MPL-01-220
Revision 0
August 1985
32.801.0346

GRAND GULF IN-PLANT SAFETY RELIEF VALVE TEST FINAL REPORT

Prepared for
Mississippi Power & Light Company

Prepared by
NUTECH Engineers, Inc.
San Jose, California

Prepared by:	Approved by:
I. D. McInnes, P.E.	M. Taylor, P.E.
Project Engineer	Project Manager
W. J. McConaghy, P.E.	for R. A. Smith
Engineering Manager	Q. A. Administrator
	Date August 19, 1985

nutech ENGINEERS

REVISION CONTROL SHEET

TITLE: Grand Gulf In-Plant Safety Relief Valve Test Final Report

REPORT NUMBER: MPL-01-220

A. F. Deardorff, P.E., Supervising Engineer — RGM for AFD (INITIALS)

J. R. Bondre, Ph.D., Consultant II — JRB (INITIALS)

R. J. Grossenbacker, Sr. Consultant — RJG (INITIALS)

I. D. McInnes, P.E., Staff Engineer — IDM (INITIALS)

L. D. Suckow, Senior Technician — IDM for LDS (INITIALS)

PAGE(S)	REV	PREPARED BY / DATE	ACCURACY CHECK BY / DATE	CRITERIA CHECK BY / DATE	REMARKS
i-xii	0	IDM /8/16/85	RGM for AFD/8/16/85	N/A	
1.1-1.2	0	IDM /8/16/85	↓	↓	
2.1	0	IDM /8/16/85	↓	↓	
3.1-3.2	0	IDM /8/16/85	RGM for AFD/ 8/16/85	↓	
3.3-3.6	0	RJG 8/16/85	IDM / 8.16.85	↓	
3.7-3.16	0	IDM /8/16/85	RGM for AFD/ 8/16/85	↓	
3.17-3.20	0	RJG 8/16/85	IDM / 8.16.85	↓	
3.21-3.33	0	IDM /8/16/85	RGM for AFD/ 8/16/85	↓	
4.1-4.2	0	↕	↓	↓	
5.1	0	↕	RGM for AFD/ 8/16/85	↓	
6.1-6.5	0	↕	JRB/8.16.85	↓	
7.1-7.12	0	IDM 8.16.85	RGM for AFD/ 8/16/85	↓	
7.13-7.19	0	LDS / 8.16.85	JRB/8.16.85	↓	
7.20-7.44	0	JRB/8.16.85	IDM / 8.16.85	↓	
8.1-8.3	0	IDM / 8.16.85	RGM for AFD/ 8/16/85	↓	
8.4-8.26	0	JRB/8.16.85	IDM / 8.16.85	N/A	

QEP 3-3.1.1 REV 0

REVISION CONTROL SHEET
(CONTINUATION)

TITLE: Grand Gulf In-Plant Safety Relief Valve Test Final Report

DOCUMENT FILE NUMBER: MPL-01-220

AFFECTED PAGE(S)	DOC REV	PREPARED BY / DATE	ACCURACY CHECK BY / DATE	CRITERIA CHECK BY / DATE	REMARKS
9.1-9.28	0	IDM / 8-16-85	JQM for AFD / 8/16/85	N/A	
10.1-10.2	0	↓	↓	↓	
11.1-11.2	0	↓	↓	↓	
App. A	0	↓	↓	↓	
App. B	0	IDM / 8-16-85	JQM for AFD / 8/16/85	N/A	

PAGE ______ OF ______

QEP 3-3.1.2
REV 1

EXECUTIVE SUMMARY

A Safety Relief Valve test program was conducted at the Grand Gulf Nuclear Power Station, Unit 1 on April 23 through 25, 1985. The purpose of the Grand Gulf test program was to confirm that the Grand Gulf SRV hydrodynamic loads and their effect on structures and equipment are: (1) less than design, and (2) consistent with the loads and effects predicted by analytical techniques.

This report describes the testing, test instrumentation, data reduction and presents the results of the Grand Gulf in-plant Safety Relief Valve (SRV) Test. Major conclusions drawn from the data reduction of the SRV test conducted at Grand Gulf are as follows:

- The measured peak pressures during the single valve first actuation (SVA), consecutive actuation (CVA) and the simultaneous actuation of multiple valves (MVA) are well below the design values for Grand Gulf.

- The pressure time history data compare favorably to the methodology developed by the General Electric Company and reported in GESSAR. This is published as Appendix 6D of the Grand Gulf FSAR. The air clearing/water spike, observed in the Kuosheng tests, is less pronounced at Grand Gulf. The CVA time histories are similar to that predicted by GESSAR, including a similar ratio of peak positive to peak negative pressure.

- The measured strains in the basemat and the containment liners, the quencher supports and the submerged structures are considerably less than the predicted values.

- The peak measured accelerations at all locations are well below the design values.

- The enveloped acceleration response spectra for SVA, CVA and MVA are well below the Grand Gulf SRV design spectra. There are some minor exceedences in the high frequency range of the spectra. However, as expected, these have little influence on the structural response.

Based on the above it is concluded that the effects of SRV hydrodynamic loads have been adequately covered in the original plant design and there are substantial margins in the SRV discharge loads, and their predicted effects, used for the Grand Gulf design.

TABLE OF CONTENTS

TABLE OF CONTENTS
(Concluded)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES
(Continued)

LIST OF FIGURES
(Continued)

LIST OF FIGURES
(Concluded)

1.0 INTRODUCTION

A major portion of the planned Safety/Relief Valve (SRV) Discharge test for the Grand Gulf Nuclear Station was conducted April 23 through April 25, 1985. This program was formulated to meet Mississippi Power and Light Company's (MP&L's) commitments as outlined in Reference 1 and modified by Reference 2. This test program provided measurements of the suppression pool hydrodynamic loads, submerged structure strains and acceleration response of the reactor building structures and equipment. In addition, data was collected to permit a fatigue evaluation of safety related equipment when subjected to building response induced by SRV discharge loads.

The test instrumentation and planned test matrix are fully described in the Test Plan, Reference 3, with the test procedures provided in References 4 and 5.

Data was collected for one shakedown test, three-initial actuations of a single valve (SVA) followed by a consecutive valve actuation (CVA) of the same valve with an elevated pipe temperature, and one four valve multiple valve actuation (MVA). The test program was suspended at this point because all test valves were leaking and additional testing was not practical until cold pipe discharge lines could be re-established.

This report describes the instrumentation, data acquisition system, data reduction methods, a brief description of the real time data collected during the test and the acceptance criteria used. A discussion of the results of the measured pressures, strains and accelerations is presented in Section 7. Measured Grand Gulf results and a comparison to the reported test results

from the SRV tests performed at the Kuosheng Nuclear Power Station in August, 1981 are presented in Sections 8 and 9.

2.0 TEST OBJECTIVES

The primary objective of the SRV in-plant test was to provide sufficient information to confirm the adequacy and conservatism of the analytical models used in the Grand Gulf containment design with respect to loadings from SRV actuations. The test matrix was established to provide measurement of Grand Gulf unique pool pressure time histories, structural loads, and acceleration responses during various SRV actuations. Multiple tests were planned to establish a statistical basis for the 95-95 confidence level used in the original design data base.

A secondary test objective was to show that the SRV imposed loads produce small stresses in the plant equipment and that SRV discharge fatigue effects would not limit the life of individual pieces of equipment. The fatigue effects results are included in a separate report.

3.0 INSTRUMENTATION SUMMARY

Pressure transducers, strain gauges, and accelerometers were installed to measure suppression pool pressures, internal pipe pressures, induced strains, and structural and equipment response to the SRV hydrodynamic loads. Tables 3.1 through 3.5 provide identification, location and environmental classifications of the installed instrumentation. Environmental conditions corresponding to each classification are defined in Table 3.6. Instrumentation locations are illustrated in Figures 3.1 through 3.12. Appendix A provides a description of the signal conditioning equipment and data acquisition system (DAS) used to process and record information from the installed instrumentation. Appendix B provides details on the operating characteristics of the individual pressure transducers, strain gauges and accelerometers used for the SRV test. The system and instrumentation used to measure and record the data taken during the Grand Gulf SRV test has been qualified by use in similar testing and qualification of the individual pieces that make up the total instrumentation package.

3.1 Instrumentation

The suppression pool boundary pressure data was collected using twenty six pressure transducers located on the basemat, the drywell, the containment, and the weir wall as shown in Table 3.1 and Figures 3.1 and 3.2. Four high range and two low range pressure transducers were located in the V-12 safety relief valve discharge line (SRVDL), and in the quencher hub and arm for quencher V-12 as shown in Table 3.1 and Figures 3.2,

3.3, and 3.6. The low range pressure sensors (P25 and P28) were installed to provide an indication of the V-12 SRVDL reflood behavior.

Thirty four strain gauges were installed to collect representative strain data during the matrix tests. As noted in Section 3.3, two strain gauges (SG9 and SG15) suffered irrepairable mechanical damage prior to the tests; therefore, thirty two (32) channels of strain data were collected for each of the seven tests performed. Strain gauges were located on the V-12 quencher support, the containment base and wall liner adjacent to quenchers V-10 and V-11, and on submerged piping. The locations of strain gauges are shown in Table 3.2 and Figures 3.4 and 3.5. An additional twenty (20) strain gauges were placed on reactor building equipment to determine the SRV discharge load fatigue stresses on plant equipment. These strain gauges were recorded on the DAS but the discussion of results for these gauges is not part of this report and is covered separately.

Fifty-six channels of accelerometer data were collected for each of the seven tests. As shown in Tables 3.3, 3.4, and Figures 3.7 through 3.12, fourteen accelerometers were located on the containment vessel, five sets of biaxial accelerometers mounted on the drywell, two sets on the RPV pedestal, and two biaxial sets in the Auxiliary Building. In addition, eight sets of triaxial accelerometers were mounted on the polar crane, hydrogen recombiner and five valve actuators.

All instrumentation was calibrated in accordance with the calibration procedures. Due to the long time interval between instrumentation installation and testing all

pressure sensors and accelerometers were recalibrated prior to testing.

3.2 Accuracy of Instrumentation

The total end-to-end accuracy (from the sensing element to data recorder) of each sensor group in the Grand Gulf In-Plant SRV test was analyzed to determine instrumentation system compatibility with respect to expected test results. As described in Appendix B the following sensor types were used to measure data:

1) Bell & Howell pressure transducers
2) Teledyne Taber pressure transducer
3) Endevco Accelerometers
4) Ailtech strain gauges

Data from the sensors were recorded on magnetic tape. Table 3.7 lists the accuracy of the recording system for each sensor. Tables 3.8 through 3.10 summarize the results of the data accuracy analysis. Note that all data were filtered at 200 Hz before being recorded on magnetic tape.

An estimate of sensor accuracy can be determined if the following characteristics are known regarding the data and the data acquisition system:

1) Accuracies of the data acquisition system components, from sensing element to recording of the data, and the appropriate conditions to apply these accuracies.

2) Characteristics of the data recorded, such as magnitude and frequency.

3) Test conditions which influence the data. These can include noise, vibration, and temperature effects.

In determining the accuracy of the Grand Gulf SRV test data, the maximum or peak values were chosen for each sensor group. The following sections discuss the data obtained for each sensor group.

3.2.1 Pressure Transducers

Pressure transducers in the Grand Gulf test were the normal operating temperature Bell & Howell CEC-1000-0207 (0 to 100 psia), the high temperature Bell & Howell CEC-1000-0208 (0 to 1000 psia) and the Teledyne Taber 2215 (0 to 50 psia). The CEC-1000-0207 transducers were used to measure suppression pool pressure, while the CEC-1000-0208 transducers were used to measure discharge line and internal quencher pressures. The Teledyne Taber transducer was installed to provide an indication of the SRVDL reflood height.

As shown in Table 3.8, the total accuracies for the pressure data are influenced by three components in the data gathering system:

1) Bell & Howell or Teledyne Taber pressure transducer
2) Vishay signal conditioner
3) QSI data acquisition system

The Bell & Howell pressure transducers have a maximum error of ±0.20% of full range output (FRO) for the 0 to 100 psia transducers, and ±0.22% for the 0 to 1000 psia transducers. The Teledyne Taber pressure transducer has

a maximum error of ±0.5%. These errors are primarily affected by non-linearity, hysteresis, non-repeatability and thermal effects.

The Vishay 2100 signal conditioner has a maximum error of ±2% on amp gain and ±1% on calibration, yielding a total error of ±2.2%.

The Quad Systems, Inc. Model 721 data recording system has an accuracy of ±1/2 least significant bit (LSB). In a 12-bit, ±5 volt full scale system, this implies an accuracy of ±0.00122 volts.

As shown in Table 3.8 the overall accuracies of the pressure transducers is ±4% of the peak measured pressure.

3.2.2 Accelerometers

Accelerometers for the Grand Gulf SRV test were either Endevco 7703-100, 7704-100, 7705-200 or 7708-200 isoshear piezoelectric devices. The 7703 and 7704 accelerometers (0-500 g's) were outside containment sensors while the 7705 and 7708s accelerometers (0 to 150 g's) were located inside the containment and drywell.

As shown in Table 3.9, the total error for the accelerometer data are affected by three components in the data gathering system:

1) Endevco accelerometer

2) Endevco charge amplifier or remote charge converter signal conditioner

3) QSI data acquisition system

The maximum error of the Endevco accelerometers is ±5.8% based on linear deviation of ±5% from 1 Hz to 4 KHz and a transverse sensitivity of ±3%.

The Endevco 2721 AM1 charge amplifiers have a frequency response of ±5% and gain accuracy of ±2%. This implies an overall accuracy of ±7.0%. The Endevco line driver signal conditioner/power rack 4479.1M3/4902 and 2652 M11 remote charge converter maintain a maximum system error of ±3% of full scale.

As stated previously, the QSI-721 data acquisition system is accurate to ±0.00122 V.

As shown in Table 3.9 the overall accuracy of the accelerometers range from ±6.5 to ±10.6% of the peak measured accelerations.

3.2.3 Strain Gauges

Ailtech Model MG125 weldable gauges were used to gather data on pool structures and piping. These gauges have rated strain levels of ±20,000 μin/in.

The Ailtech gauge factor maximum error is ±3%. The accuracy of the Vishay 2100 has been previously discussed in Section 3.2.1.

As shown by Table 3.10 the overall strain gauge accuracy is ±4% of the peak measured strain.

3.2.4 Summary

Many of the readings taken during the SRV tests were of small magnitude compared to the capabilities of the measuring devices. The above discussion demonstrates that despite these small magnitudes the instrumentation has the capability to provide measurements of the data which are within ±10%. This is well within acceptable limits of accuracy.

3.3 Failed or Suspect Sensors

Failure or erratic performance of some instrumentation is inherent when conducting in-plant tests. Upon reviewing the reduced data, sensors which failed or behaved erratically were identified. Table 3.11 lists these sensors and includes remarks on the effect of their failure with respect to the overall objectives of the test program. Results from all sensors listed in Table 3.11 are ignored in this test report for the matrix test, or tests, in which they failed or were suspect. The failure of strain gauges SG9 and SG15 was known prior to the tests and channels were not recorded on the data acquisition system. This reduced the total number of data channels recorded from 142 to 140.

Table 3.1

PRESSURE TRANSDUCER LOCATIONS AND RESPONSE RANGES

SENSOR TYPE	SENSOR ID	LOCATION			EXPECTED RESPONSE	FREQUENCY RANGE	ENVIRON-MENT	NOTES
		AZIMUTH	ELEVATION	RADIUS				
Pressure	P1	32°	98'-0 1/4"	41'-6"	10-35 psia	0-200 Hz	E1	Suppression Pool Sensors
Pressure	P2	29.5°	93'-0 1/4"	54'-10"	10-35 psia	0-200 Hz	E1	
Pressure	P3	32°	93'-6"	62'-0"	10-35 psia	0-200 Hz	E1	
Pressure	P4	16°	107'-0"	41'-6"	10-35 psia	0-200 Hz	E1	
Pressure	P5	16°	102'-4"	41'-6"	10-35 psia	0-200 Hz	E1	
Pressure	P6	16°	98'-0 1/4"	41'-6"	10-35 psia	0-200 Hz	E1	
Pressure	P7	16°	93'-0 1/4"	51'-3 3/8"	10-35 psia	0-200 Hz	E1	
Pressure	P8	24°	93'-0 1/4"	48'-0"	10-35 psia	0-200 Hz	E1	
Pressure	P9	16°	93'-6"	62'-0"	10-35 psia	0-200 Hz	E1	
Pressure	P10	15.5°	98'-0 1/4"	62'-0"	10-35 psia	0-200 Hz	E1	
Pressure	P11	15.5°	107'-0"	62'-0"	10-35 psia	0-200 Hz	E1	
Pressure	P12	8°	93'-0 1/4"	44'-2 3/8"	10-35 psia	0-200 Hz	E1	
Pressure	P13	0°	98'-0 1/4"	41'-6"	10-35 psia	0-200 Hz	E1	
Pressure	P14	358°	93'-0 1/4"	51'-4 3/8"	10-35 psia	0-200 Hz	E1	
Pressure	P15	0°	98'-0 1/4"	62'-0"	10-35 psia	0-200 Hz	E1	
Pressure	P16	344°	98'-0 1/4"	41'-6"	10-35 psia	0-200 Hz	E1	

Table 3.1 (Concluded)

PRESSURE TRANSDUCER LOCATIONS AND RESPONSE RANGES

SENSOR TYPE	SENSOR ID	LOCATION AZIMUTH	LOCATION ELEVATION	LOCATION RADIUS	EXPECTED RESPONSE	FREQUENCY RANGE	ENVIRON-MENT	NOTES
Pressure	P17	344°	93'-0 1/4"	51'-6"	10-35 psia	0-200 Hz	E1	)
Pressure	P18	255°	93'-0 1/4"	51'-6"	10-35 psia	0-200 Hz	E1	) Suppression Pool Sensors
Pressure	P19	309°	93'-0 1/4"	51'-6"	10-35 psia	0-200 Hz	E1	)
Pressure	P20	195°	93'-0 1/4"	51'-6"	10-35 psia	0-200 Hz	E1	)
Pressure	P21	-------See Figure 3.3------			0-400 psia	0-200 Hz	E5	- Downstream of SRV
Pressure	P22	-------See Figure 3.3------			0-400 psia	0-200 Hz	E5	- Downstream of SRV
Pressure	P23	-------See Figure 3.3------			0-700 psia	0-200 Hz	E4	- Inside Quencher Hub
Pressure	P24	-------See Figure 3.3------			0-700 psia	0-200 Hz	E4	- Inside Quencher Arm
Pressure	P25	-------See Figure 3.3------			0-25 psia	0-200 Hz	E5	- Low Range Pressure Sensor - Downstream of SRV
Pressure	P26	12°	104'-4"	34'-0"	10-35 psia	0-200 Hz	E1	Weir Wall
Pressure	P27	12°	100'-2"	34'-0"	10-35 psia	0-200 Hz	E1	Weir Wall
Pressure	P28	-------See Figure 3.6-----			0-35 psia	0-200 Hz	E2	- Low Range Pressure Sensor - V-12 Air Bleed System
Pressuer	P29	200°	94'-5 5/1"	43'-6"	10-35 psia	0-200 Hz	E1	Suppression Pool Sensors
Pressure	P30	456	94'-5 5/1"	43'-6"	10-35 psia	0-200 Hz	E1	
Pressure	P31	119°50'	94'-5 5/1"	43'-6"	10-35 psia	0-200 Hz	E1	
Pressure	P32	120°10'	94'-5 5/1"	43'-6"	10-35 psia	0-200 Hz	E1	

Table 3.2

STRAIN GAUGE LOCATIONS AND RESPONSE RANGES

SENSOR TYPE	SENSOR ID	LOCATION AZIMUTH	LOCATION ELEVATION	LOCATION RADIUS	EXPECTED RESPONSE in/in	FREQUENCY RANGE	ENVIRON-MENT	NOTES
Strain Gage	SG1	0°	93'-0 1/4"	53'-3"	0.0001-0.001	0-200 Hz	E1	Short Plate Axis
Strain Gage	SG2	0°	93'-0 1/4"	53'-3"	0.0001-0.001	0-200 Hz	E1	Long Plate Axis
Strain Gage	SG3	0°	93'-0 1/4"	60'-3"	0.0001-0.001	0-200 Hz	E1	Short Plate Axis
Strain Gage	SG4	0°	93'-0 1/4"	60'-3"	0.0001-0.001	0-200 Hz	E1	Long Plate Axis
Strain Gage	SG5	-------See Figure 3.4------			0.0001-0.001	0-200 Hz	E1	Axial, Quencher Base
Strain Gage	SG6	-------See Figure 3.4------			0.0001-0.001	0-200 Hz	E1	Axial, Quencher Base
Strain Gage	SG7	-------See Figure 3.4------			0.0001-0.001	0-200 Hz	E1	Axial, Quencher Base
Strain Gage	SG8	-------See Figure 3.4------			0.0001-0.001	0-200 Hz	E1	Rosette, Quencher Base
Strain Gage	SG9	-------See Figure 3.4------			0.0001-0.001	0-200 Hz	E1	Rosette, Quencher Base
Strain Gage	SG10	-------See Figure 3.4------			0.0001-0.001	0-200 Hz	E1	Rosette, Quencher Base
Strain Gage	SG11	8°	93'-0 1/4"	53'-0"	0.0001-0.001	0-200 Hz	E1	Short Plate Axis
Strain Gage	SG12	8°	93'-0 1/4"	53'-0"	0.0001-0.001	0-200 Hz	E1	Long Plate Axis
Strain Gage	SG13	0.5°	98'-0 1/4"	62'-0"	0.0001-0.001	0-200 Hz	E1	Vertical
Strain Gage	SG14	0.5°	98'-0 1/4"	62'-0"	0.0001-0.001	0-200 Hz	E1	Horizontal
Strain Gage	SG15	---See Figures 3.4 and 3.5 --			0.0001-0.001	0-200 Hz	E1	Axial, RCIC turbine exhaust
Strain Gage	SG16	---See Figures 3.4 and 3.5 --			0.0001-0.001	0-200 Hz	E1	Axial, RCIC turbine exhaust

Table 3.2 (Continued)

STRAIN GAUGE LOCATIONS AND RESPONSE RANGES

SENSOR TYPE	SENSOR ID	LOCATION			EXPECTED RESPONSE in/in	FREQUENCY RANGE	ENVIRON-MENT	NOTES
		AZIMUTH	ELEVATION	RADIUS				
Strain Gage	SG17	--See Figures 3.4 and 3.5--			0.0001-0.001	0-200 Hz	E1	Axial, RCIC turbine exhaust
Strain Gage	SG18	--See Figures 3.4 and 3.5--			0.0001-0.001	0-200 Hz	E1	Axial, RCIC turbine exhaust
Strain Gage	SG19	--See Figures 3.4 and 3.5--			0.0001-0.001	0-200 Hz	E1	Axial, RHR A pump test
Strain Gage	SG20	--See Figures 3.4 and 3.5--			0.0001-0.001	0-200 Hz	E1	Axial, RHR A pump test
Strain Gage	SG21	--See Figures 3.4 and 3.5--			0.0001-0.001	0-200 Hz	E1	Axial, RHR A pump test
Strain Gage	SG22	--See Figures 3.4 and 3.5--			0.0001-0.001	0-200 Hz	E1	Rosette, RHR A pump test
Strain Gage	SG23	--See Figures 3.4 and 3.5--			0.0001-0.001	0-200 Hz	E1	Rosette, RHR A pump test
Strain Gage	SG24	--See Figures 3.4 and 3.5--			0.0001-0.001	0-200 Hz	E1	Rosette, RHR A pump test
Strain Gage	SG25	0.5°	109'-1 1/2"	62'-0"	0.0001-0.001	0-200 Hz	E1	Horizontal
Strain Gage	SG26	0.5°	109'-1 1/2"	62'-0"	0.0001-0.001	0-200 Hz	E1	Vertical
Strain Gage	SG27	8.5°	98'-0 1/4"	62'-0"	0.0001-0.001	0-200 Hz	E1	Horizontal
Strain Gage	SG28	8.5°	98'-0 1/4"	62'-0"	0.0001-0.001	0-200 Hz	E1	Vertical
Strain Gage	SG29	-------See Figure 3.5 ------			0.0001-0.001	0-200 Hz	E1	Rosette, Quencher Base
Strain Gage	SG30	-------See Figure 3.5 ------			0.0001-0.001	0-200 Hz	E1	Rosette, Quencher Base
Strain Gage	SG31	-------See Figure 3.5 ------			0.0001-0.001	0-200 Hz	E1	Rosette, Quencher Base

Table 3.2 (Concluded)

STRAIN GAUGE LOCATIONS AND RESPONSE RANGES

Strain Gage	SG32	-------See Figure 3.5------	0.0001-0.001	0-200 Hz	El	Axial, Quencher Base
Strain Gage	SG33	-------See Figure 3.5------	0.0001-0.001	0-200 Hz	El	Axial, Quencher Base
Strain Gage	SG34	-------See Figure 3.5------	0.0001-0.001	0-200 Hz	El	Axial, Quencher Base

Table 3.3

LOCATION OF ACCELEROMETERS - STRUCTURE

Sensor I.D.	Location			Environ-ment	Direc-tion (1)
	Azimuth	Elev.	Radius		
Reactor Building Sensors:					
A1	32°	93.0'	65'0"	E2	R
A2	32°	93.0'	65'0"	E2	V
A3	32°	109.12'	65'0"	E2	R
A4	32°	109.12'	65'0"	E2	V
A5	302°	109.12'	65'0"	E2	R
A6	302°	109.12'	65'0"	E2	T
A7	0°	147.58'	62'0"	E2	R
A8	0°	147.58'	62'0"	E2	V
A9	270°	147.58'	62'0"	E2	R
A10	270°	147.58'	62'0"	E2	T
A11	32°	237.0'	62'0"	E2	R
A12	32°	237.0'	62'0"	E2	V
A13	32°	302.25'	0'0"	E2	V
A14	32°	302.25'	0'0"	E2	R
A15	32°	120.83'	41'6"	E2	R
A16	32°	120.83'	41'6"	E2	V
A17	302°	120.83'	41'6"	E2	R
A18	302°	120.83'	41'6"	E2	T
A19	0°	147.58'	41'6"	E2	R
A20	0°	147.58'	41'6"	E2	V
A21	302°	184.5'	41'0"	E2	R
A22	302°	184.5'	41'0"	E2	T
A23	32°	208.83'	41'6"	E2	R
A24	32°	208.83'	41'6"	E2	V
A25	0°	100.75'	10'7"	E2	R
A26	0°	100.75'	10'7"	E2	V
A27	270°	100.75'	10'7"	E2	R
A28	270°	100.75'	10'7"	E2	T
Auxiliary Building Sensors:					
A53	32°	93.0'	68'0"	E2	R
A54	32°	93.0'	68'0"	E2	V
A55	32°	184.5'	66'0"	E2	V
A56	32°	184.5'	66'0"	E2	R

NOTES: (1) R = Horizontal, radial
V = Vertical
T = Horizontal, tangential

Table 3.4

LOCATION OF ACCELEROMETERS - EQUIPMENT

Sensor ID	Equipment Description	Location		Direction	Comments
		Azimuth	Elevation		
A29 A30 A31	Polar Crane Girder	0°	237'0"	R (0°-180°) V T (90-270°)	Crane to be parked on N-S(122°-302°) azimuth during tests
A32 A33 A34	Base of Hydrogen Recombiner	130°	208'10"	R V T	
A35 A36 A37	Top of Hydrogen Recombiner	130°	208'10"	R V T	

Note: Environmental conditions are all E2.

Table 3.5

LOCATION OF ACCELEROMETERS - PIPING

SENSOR ID	BECHTEL DRAWING NO./Rev.	ELEVATION	DIRECTION (1) NO.	DATA POINT	PIPE CLASS	EQUIPMENT DESCRIPTION
A38 A39 A40	HL-1348E	101'-9"	X Y Z	140	18"-GBB-17	Valve Operator #Q1E12G014-F003B-B
A41 A42 A43	H-1328J/D	149'3-1/2"	X Y Z	30	12"-DBA-17	Snubber(X) #Q1B21G026R03
A44 A45 A46	HL-1348A	126'9-3/4"	X Y Z	135	20"-DBA-64	Valve Operator #Q1E12G012-F009-B
A47 A48 A49	HL-1348F	167'1-1/2"	X Y Z	751	12"-GBB-115	Valve Operator #Q1E12G015-F037A-A
A50 A51 A52	HL-1348F	170'9-1/2"	X Y Z	216	18"-GBB-118	Valve Oper. #Q1E12G015-F028B-B

Notes: 1. X = horizontal, azimuth 90°
Y = vertical up
Z = horizontal, azimuth 180°
2. Environmental conditions are E2 for all sensors, with the exception that the maximum temperature is 450°F.

Table 3.6

MAXIMUM EXPECTED SENSOR ENVIRONMENTAL CONDITIONS

(1) E1 - Conditions in Suppression Pool

Fluid	Water
Pressure	50 psia
Temperature	50°F-200°F

(2) E2 - Conditions in Drywell/Containment

Fluid	Air
Pressure	42.2 psia
Relative Humidity	100%
Temperature	135°F

(3) E3 - Conditions in SRV Discharge Line and Quencher Assembly

Fluid	Water/Steam/Air
Temperature	400°F
Pressure (Quencher Assembly)	700 psia
Pressure (SRV Line)	400 psia

(4) E4 - Combination of E1 and E3

Sensor will be in the SRV discharge line and the "outside" of the sensor and its cabling will be exposed to conditions in the drywell.

Table 3.7

DATA ACQUISITION SYSTEM ACCURACY

Data Acquisition System Accuracy ±1.22 mV		
Sensor	Calibration	Accuracy
P1 to P20, P25 to P32	100 mV/psi	0.012 psi
P21 to P24	5 mV/psi	0.24 psi
A1 to A6, A38, A39, A53, A54	1000 mV/g	0.00122 g
A7, A9, A11, A14, A15, A17, A19 A21, A23, A25, A27, A32, A35	8333 mV/g	0.000146 g
A8, A10, A12, A13, A16, A18, A20, A22, A24, A26, A28, A33 A34, A36, A55, A56	25000 mV/g	0.00005 g
A29	4166 mV/g	0.00029 g
A30, A31	12500 mV/g	0.00010 g
A37	2500 mV/g	0.00049 g
A40	3333 mV/g	0.00037 g
A41 to A52	833 mV/g	0.00146 g
SG1 to SG34	4 mV/ μin/in	0.31 μin/in

Table 3.8

PRESSURE TRANSDUCER ACCURACY (±)

Sensor	P1 to P20 P25 to P32	P21 to P24
Peak Reading (psid)	+7.44	282
Transducer Error (psid)	0.20	0.22
Signal Conditioner Error (psid)	0.22	8.46
Data Recorder Error (psid)	0.012	0.24
SRSS Total Error (psid)	0.298	8.47
Percent Error	4.00	3.00

Table 3.9

ACCELEROMETER ACCURACY (±)

Sensor	A1 to A6, A38, A39, A53 A54	A7, A9, A11, A14, A15, A17, A19, A21, A23, A25, A27, A32, A35	A8, A10, A12, A13, A16, A18 A20, A22, A24, A26, A28, A33 A34, A36, A55 A56	A29	A30, A31	A37	A40	A41 to A52
Peak Reading (g)	0.17	0.19	0.11	0.02	0.02	0.06	0.007	0.50
Sensor Error, (g)	0.0099	0.0110	0.0064	0.0012	0.0012	0.0035	0.0004	0.0290
Signal Conditioner/Line Drive Amplifier (g)	0.0119	0.0057	0.0033	0.0014	0.0014	0.0018	0.0005	0.0150
Data Recorder Error, (g)	0.001220	0.000146	0.000050	0.000290	0.000100	0.000490	0.000370	0.001460
SRSS Total Error, (g)	0.0155	0.0124	0.0072	0.0019	0.0018	0.0040	0.0007	0.0327
Percent Error	9.1	6.5	6.6	9.3	9.2	6.6	10.6	6.5

Table 3.10

STRAIN GAUGE ACCURACY (±)

Gauge	S1 to S34
Peak Reading (μin/in)	50
Gauge Error (μin/in)	1.5
Signal Conditioner Error (μin/in)	1.5
Data Recorder Error (μin/in)	0.31
SRSS Total Error (μin/in)	2.14
Percent Error	4.3

Table 3.11

FAILED OR SUSPECT SENSORS

Sensor Type	Sensor I.D.	Affected Tests	Remarks
Pressure Transducers	P22	All	P21 provides backup
	P24	All	P23 provides similar data
	P28	All	P25 provides backup
Strain Gauges	SG7	All	See Section 7.3.1 for discussion
	SG9	All	Principal stresses cannot be computed as S9 is 45° leg of rosette.
	SG15	All	SG16, 17 and 18 provide backup.
Accelerometers	A2	All	Acceleration data measured by A2 is inconsistent with all other data. See Section 7.4 for details
	A48	All	A47 and A49 show minimal perpendicular accelerations, consistent with other equipment mounted accelerometers.

NOTE:

1. Variations of readings due to D.C. offset, wild points and instrument errors are discussed in Section 7.0.

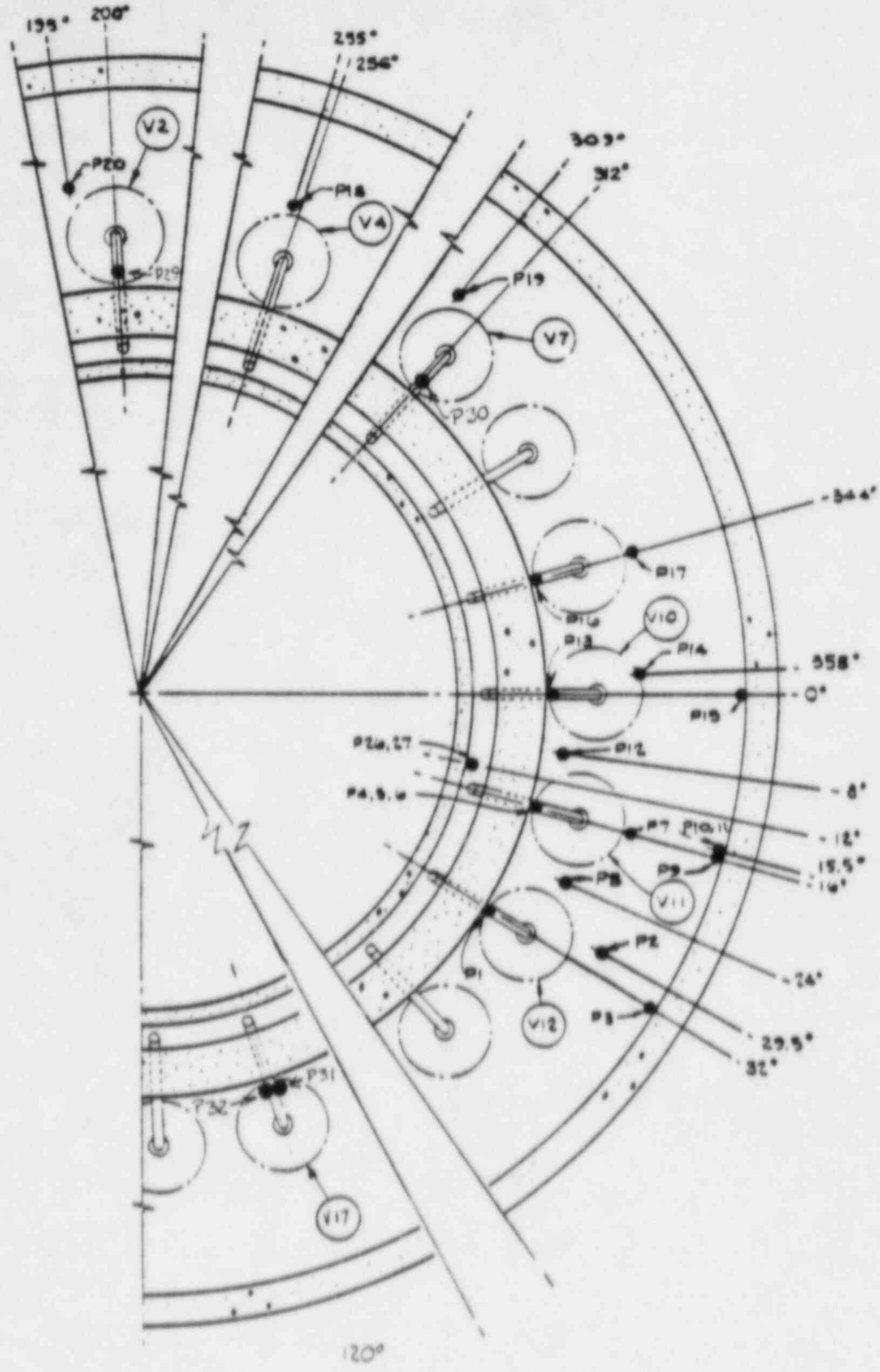


Figure 3.1

<u>SUPPRESSION POOL PRESSURE TRANSDUCER LOCATIONS -</u>

<u>PLAN VIEW</u>

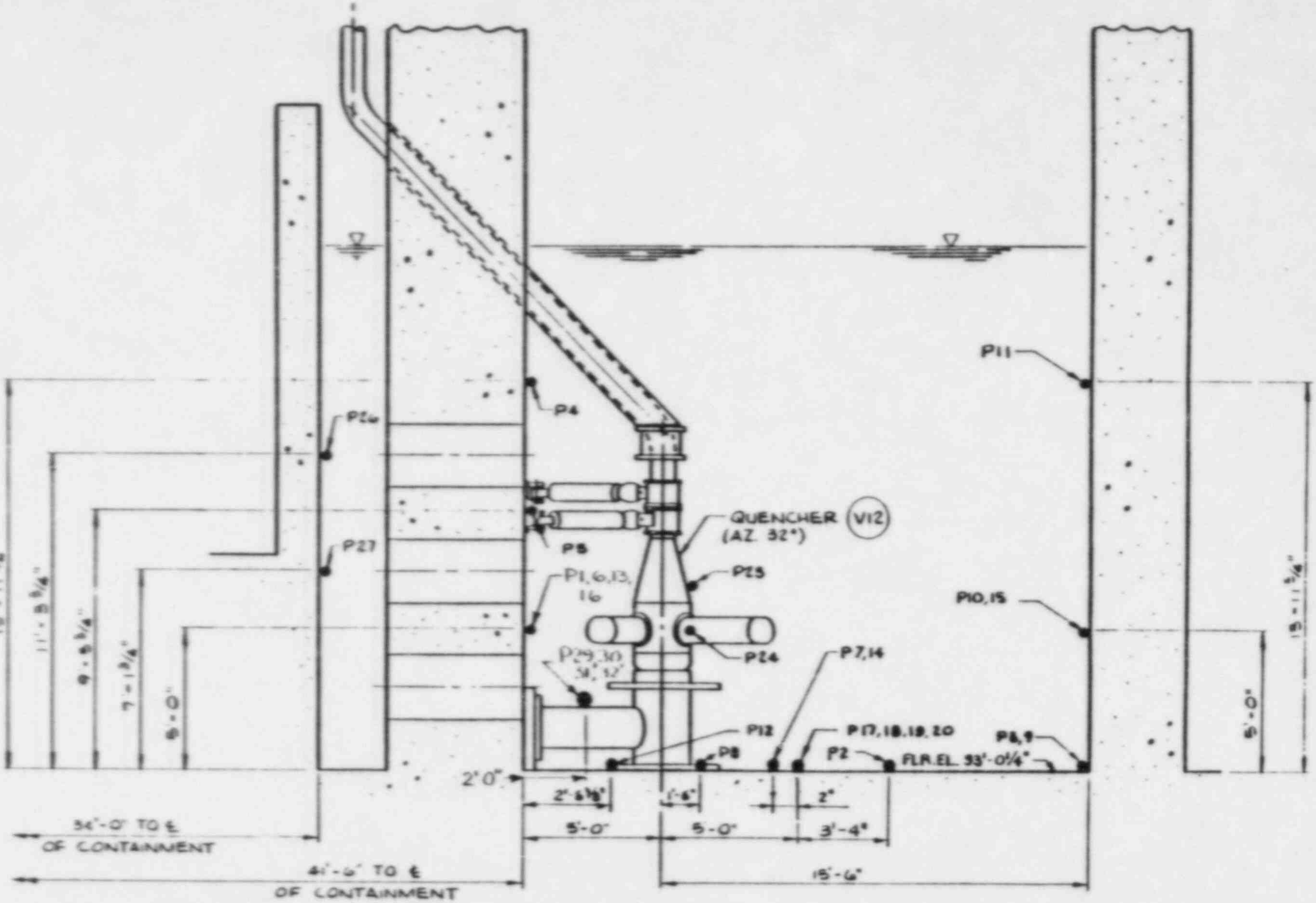


Figure 3.2

SUPPRESSION POOL PRESSURE TRANSDUCERS - ELEVATION VIEW (SENSORS ROTATED INTO VIEW)

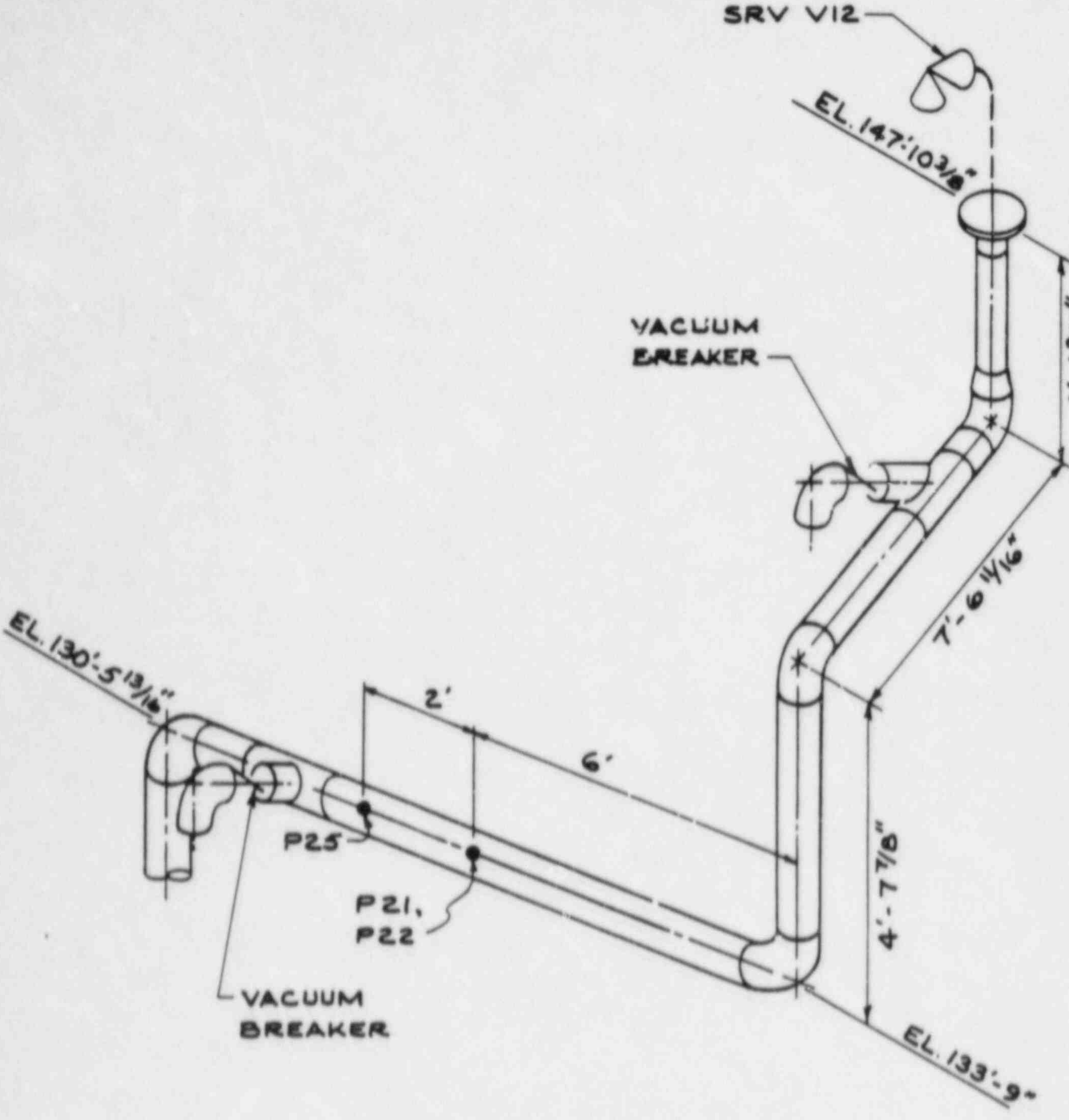


Figure 3.3

SRV DISCHARGE LINE PRESSURE TRANSDUCERS

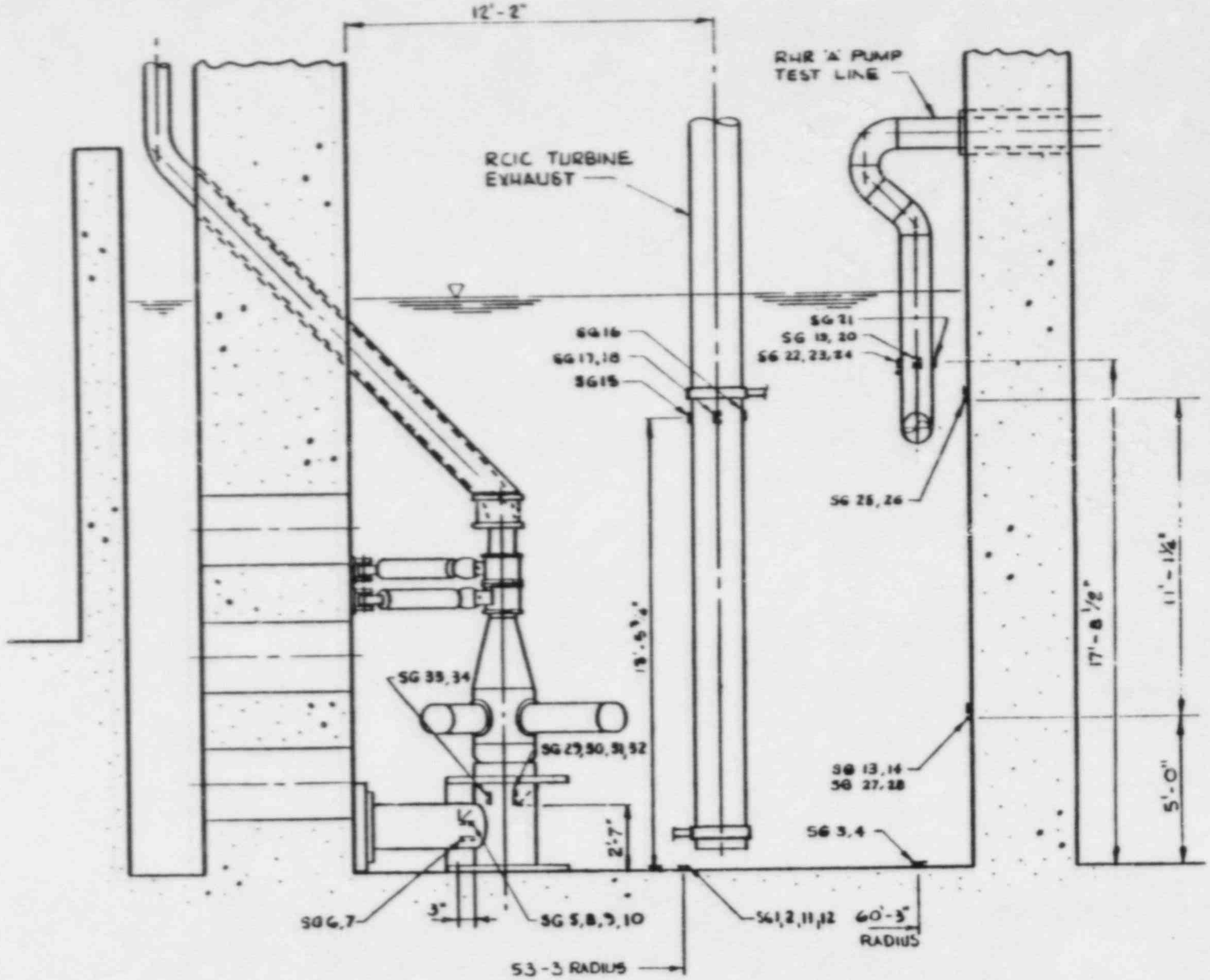


Figure 3.4

STRAIN GAUGE LOCATIONS - ELEVATION (SENSORS ROTATED INTO VIEW)

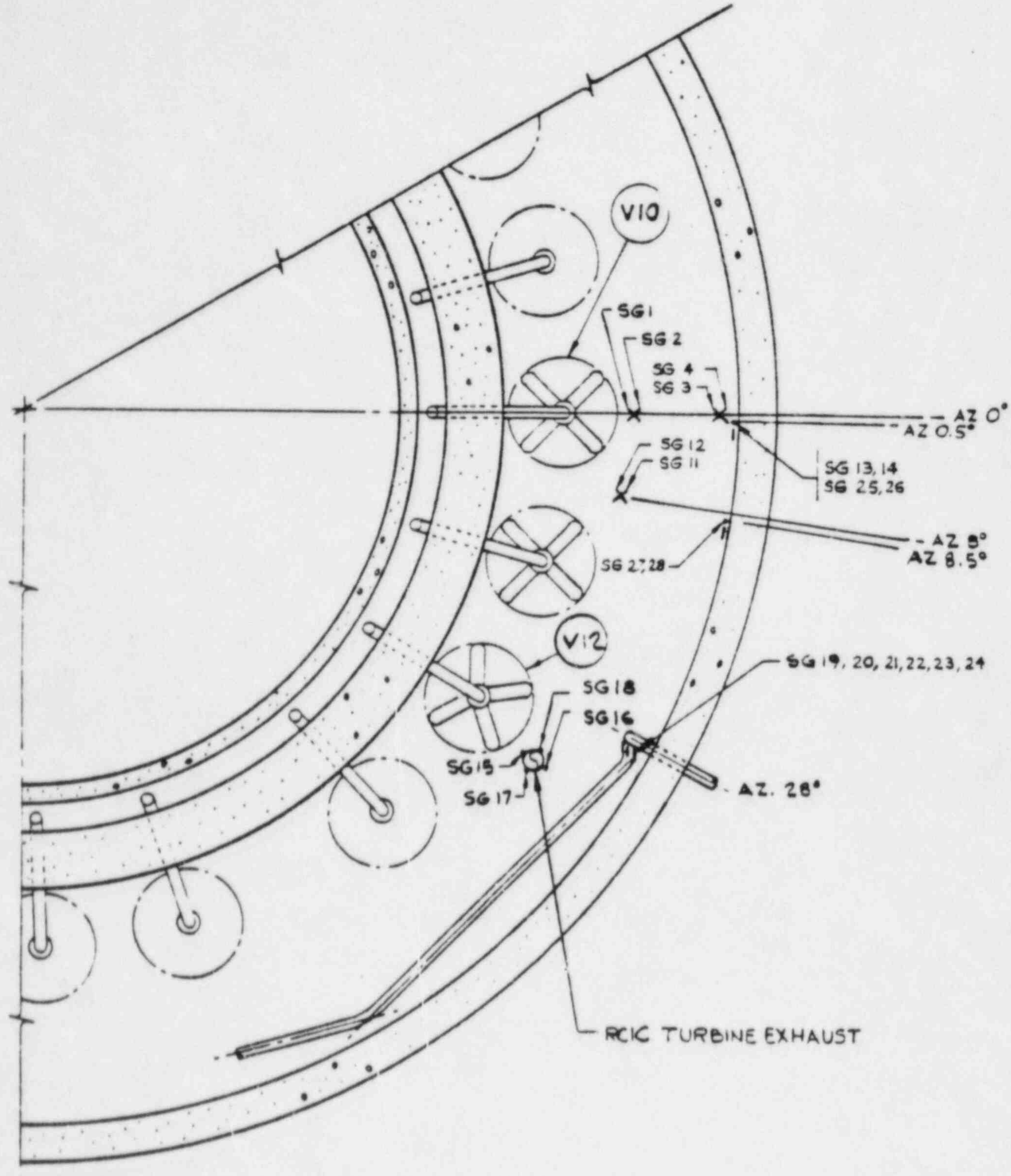


Figure 3.5

STRAIN GAUGE LOCATIONS - PLAN

nutech ENGINEERS

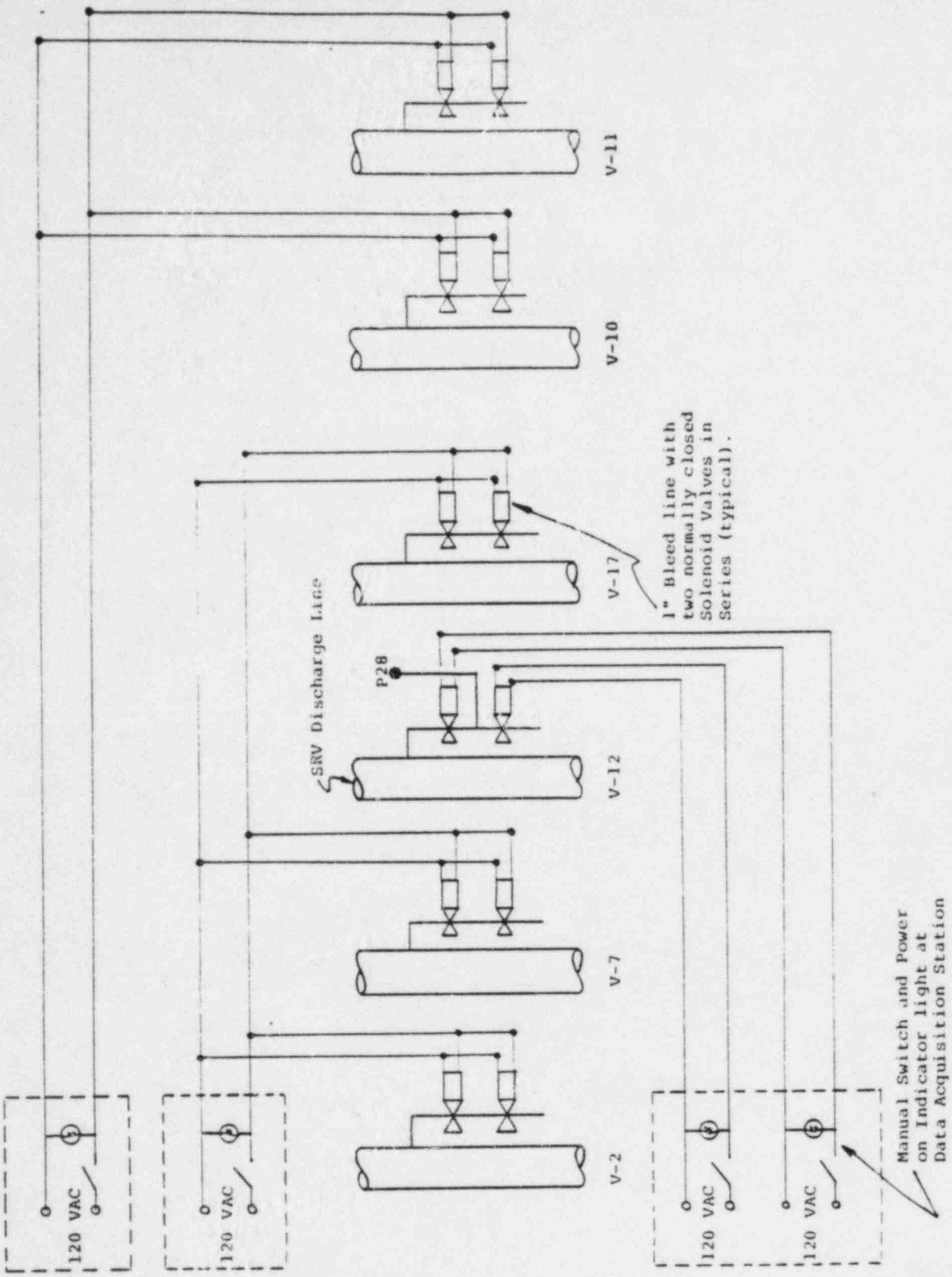


Figure 3.6

<u>SRV DISCHARGE LINE AIR BLEED SYSTEM SCHEMATIC DIAGRAM</u>

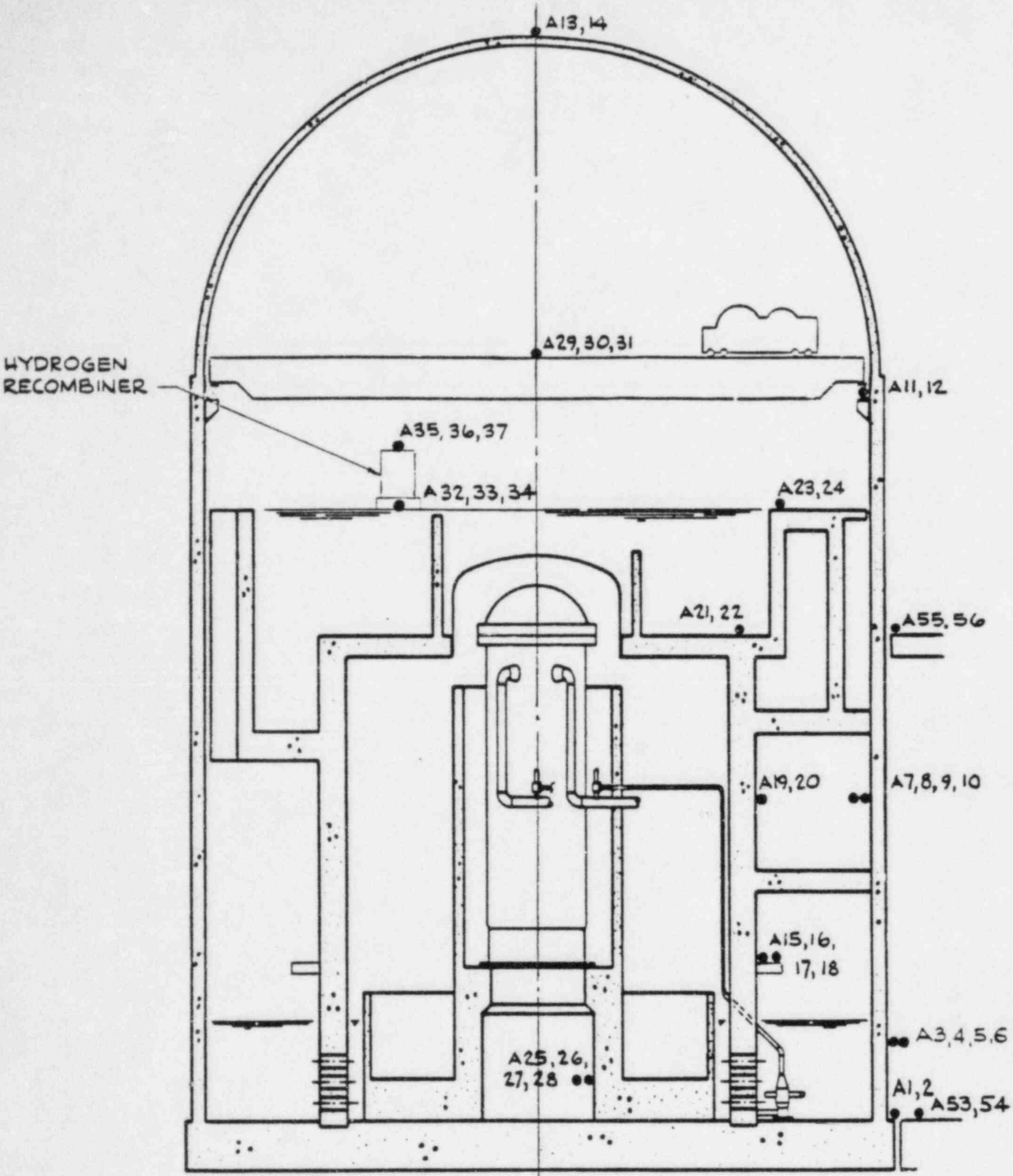


Figure 3.7

ACCELEROMETER LOCATIONS-STRUCTURE

(ELEVATION VIEW - ACCELEROMETERS ROTATED INTO VIEW)

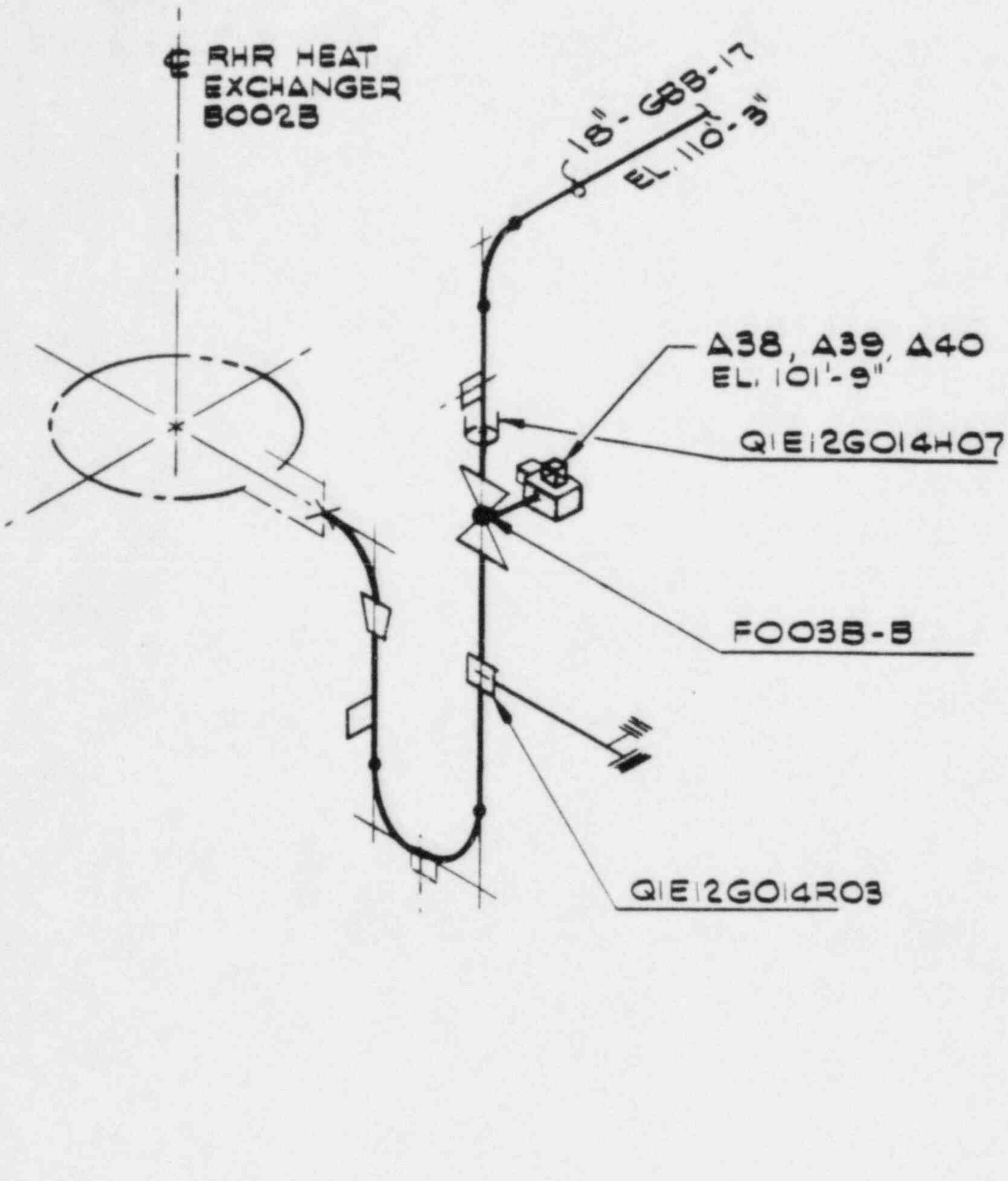


Figure 3.8

PIPE MOUNTED ACCELEROMETERS A38, A39, A40

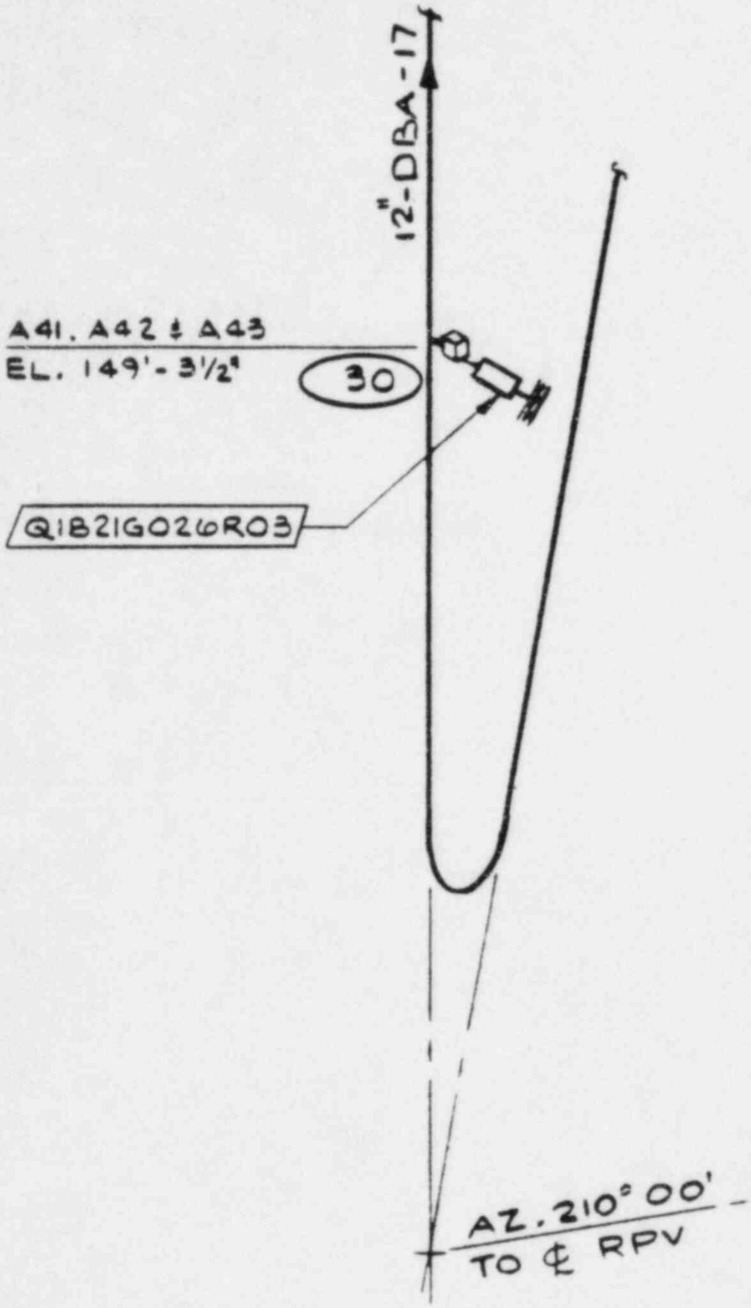


Figure 3.9

PIPE MOUNTED ACCELEROMETERS A41, A42, A43

nutech ENGINEERS

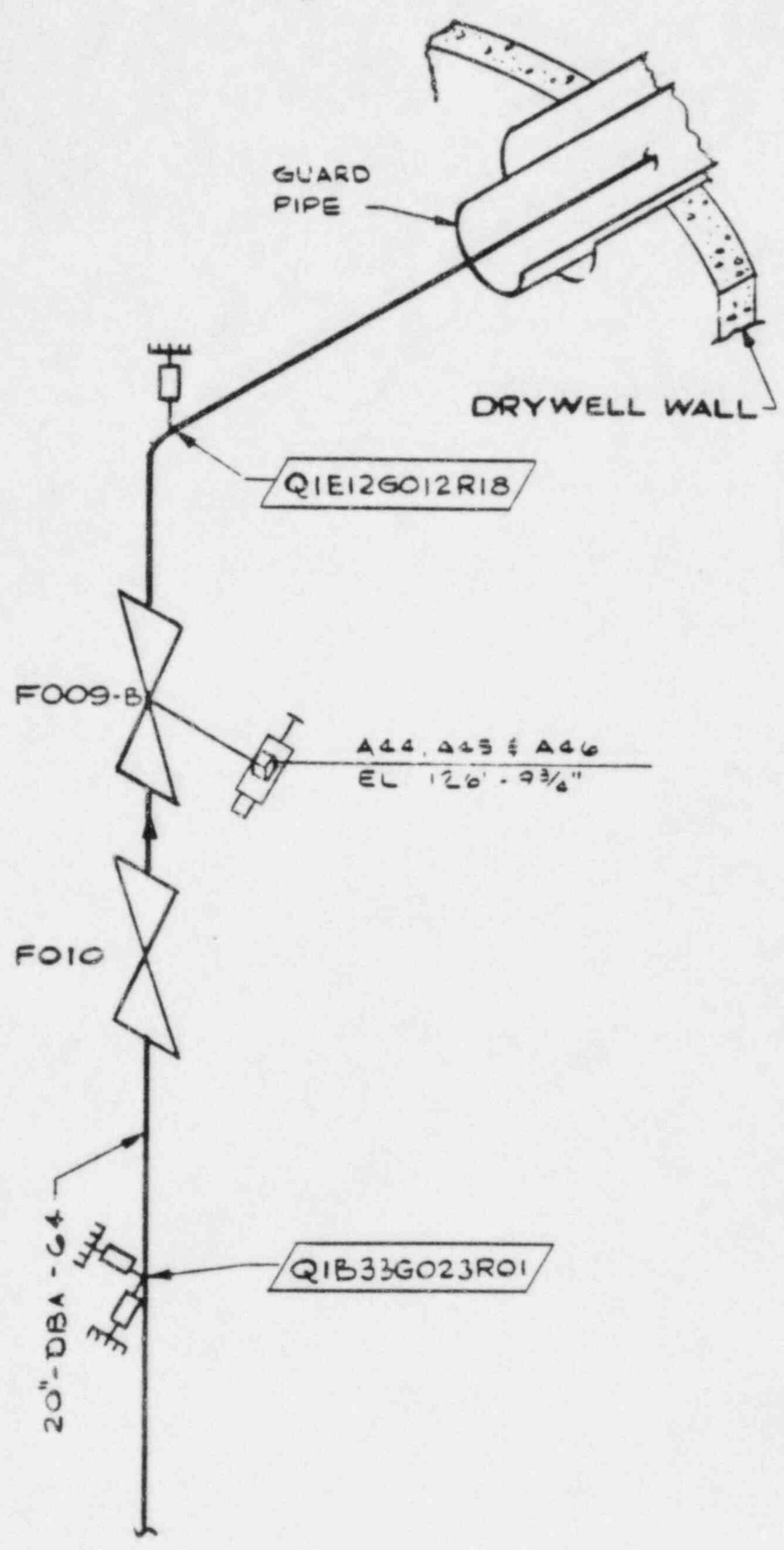


Figure 3.10

PIPE MOUNTED ACCELEROMETERS A44, A45, A46

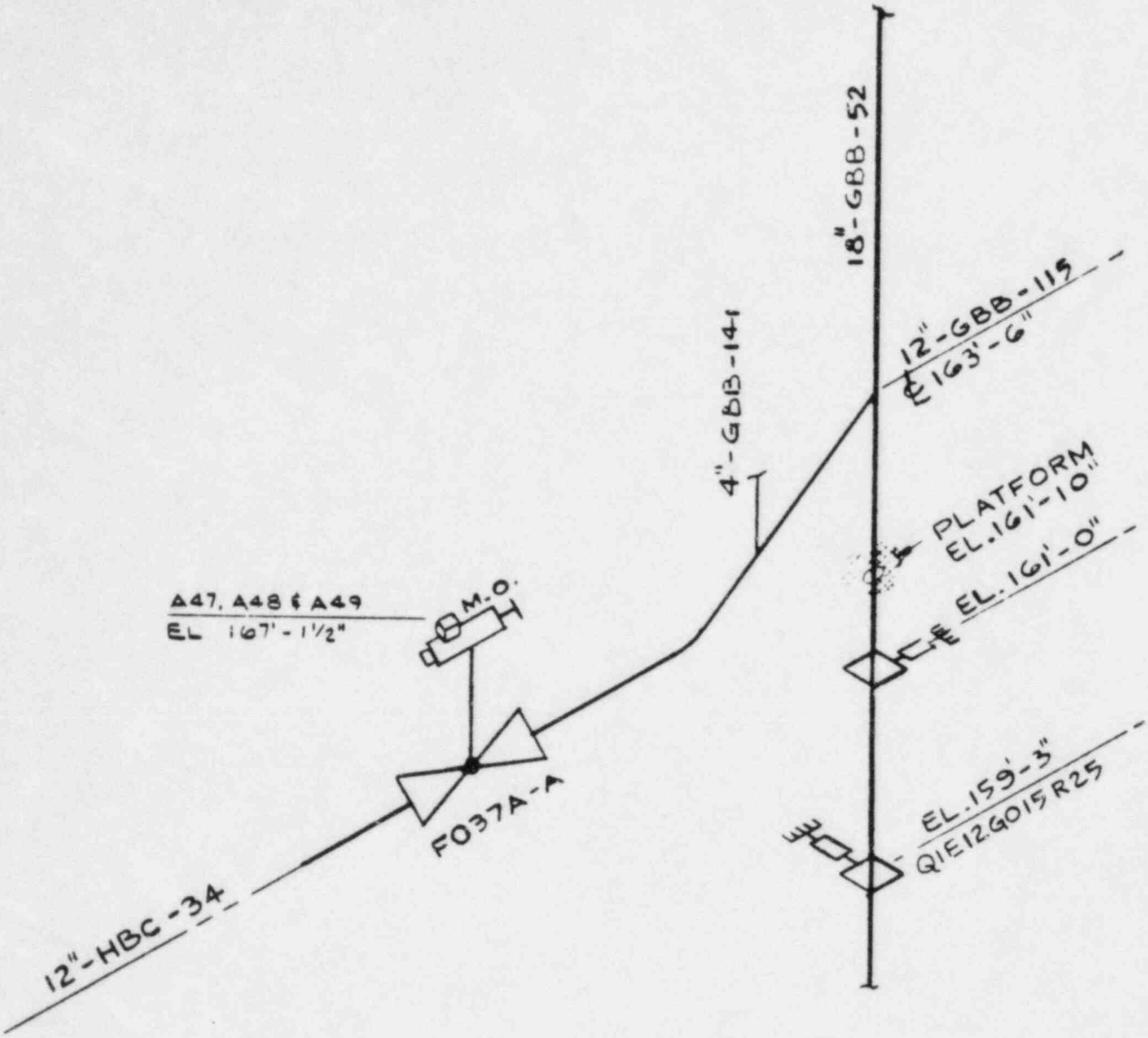


Figure 3.11

PIPE MOUNTED ACCELEROMETERS A47, A48, A49

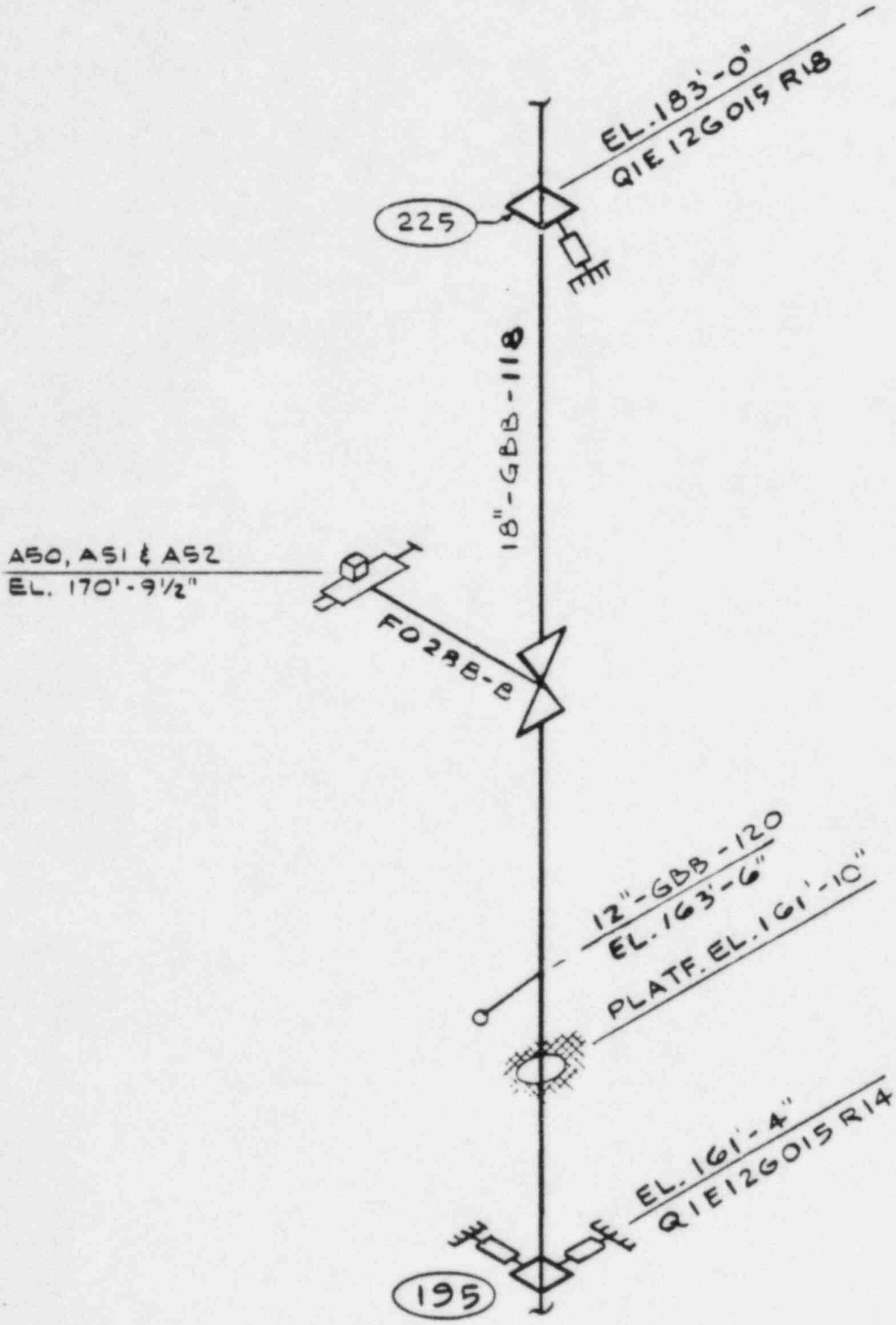


Figure 3.12

PIPE MOUNTED ACCELEROMETERS A50, A51, A52

4.0 TEST SEQUENCE AND EVENTS

The test program consists of one shakedown test, three SVA/CVA tests and one MVA test as shown by Table 4.1. Single actuation tests were conducted on the main test valve (V-12) as well as both backup valves (V-10 and V-11) with the MVA test performed on the 4 planned valves (V-2, V-7, V-12 and V-17). As noted in Table 4.1, valve V-12 was leaking prior to the MVA test, so data collected by the V-12 line and adjacent pressure sensors can be considered as indicative of typical results for a leaking valve.

The data collected, on the DAS, for the shakedown test (SD1) was lost due to a malfunction in the tape recorder. However, the real time oscillograph data recorded demonstrated that the instrumentation was functioning correctly and the signal conditioning was set at the correct gain settings. Therefore, it was concluded that the test had served its function and testing could proceed to MT10/MT11.

On completion of test MT70 all principal test valves demonstrated some degree of leakage, and the program was suspended. Following a detailed review of the data, it was determined that the SRV hydrodynamic loads were bounded by expected pressures, and the measured strains, and building and equipment responses were small compared to expected values. Results of the initial data reduction were submitted to the NRC, References 11, 12, and 13, for their review and concurrence in terminating the tests. The NRC has responded, Reference 14, that, subject to review of the final test report sufficient test data has been collected to satisfy Grand Gulf FSAR and licensing commitments and no further testing is required.

Table 4.1

TEST MATRIX

Test No.	Test Type	Valve Actuated (1)	Initial Conditions: SRVDL Water Level	Initial Conditions: Pool Temp. (°F)	Initial Conditions: Power Level (%)	Discharge Time (Sec.)	Valve Closure Time Prior to DVA (Sec.)	Reactor Press. (psig)
SD1	SVA	V-12	NWL	74	70.9	5	N/A	982.0
MT10	SVA	V-10	NWL	74	60.4	20	N/A	976.0
MT11	CVA	V-10	AWL			5	45	
MT20	SVA	V-11	NWL	74	68.0	20	N/A	983.6
MT21	CVA	V-11	AWL			5	45	
MT30	SVA	V-11	NWL	75	69.2	20	N/A	984.0
MT31	CVA	V-11	AWL			5	45	
MT70	MVA	V-2,V-7, V-12,V-17	NWL(2)	85.5	72.1	15,25,45,35	N/A	1001.7

SD = Shakedown Test SVA = Single Valve First Actuation
MT = Matrix Test CVA = Single Valve Consecutive Actuation
NWL = Normal Water Level, i.e. water surface within SRVDL is coincident with suppression pool
AWL = Actual Water Level, i.e. water level dependent on SRVDL internal pressure

(1) Control room switch designations V-2 = F041B, V-7 = F047D, V-10 = F051D, V-11 = F047A, V-12 = F041E, V-17 = F047G.
(2) V-12 was leaking during this test and SRVDL had approximately 4 psi internal pressure at test, all other lines were NWL.

5.0 REAL TIME DATA SENSORS AND ACCEPTANCE CRITERIA

During the test program data from 140 sensors were recorded on the DAS. Approximately 25% of the sensors were reviewed in real time by simultaneously recording the signals on oscillograph recorders. Acceptance criteria for all of the real time data channels were developed prior to the test and are presented in References 6 through 8 and summarized in the test procedures References 4 and 5. The Level 1 acceptance criteria were calculated based on plant design values while the Level 2 acceptance criteria are the expected results at test conditions. Exceedance of Level 2 acceptance criteria served as a warning, but did not halt testing. Exceedance of Level 1 criteria required a delay in testing until investigation of the exceedances ensured that continuation of testing would not jeopardize plant safety.

The real time channels selected for recording represented the locations of maximum expected response. The measured real time data initially showed some peak pressure and accelerometer readings which exceeded the Level 1 acceptance criteria. For each of these cases, the signals were filtered to remove frequencies above 100 Hz and recorded with a fast Fourier transform (FFT) analyzer. Each of these was investigated individually and shown to be acceptable.

6.0 DATA REDUCTION

6.1 Introduction

The measured time-histories for each of the 140 instrumentation channels, were recorded by the QSI-721 Data Acquisition System (DAS) on magnetic tape for off-line processing. The data recorded by the DAS was digitally filtered at 200 Hz during recording. As described below, the recorded time histories have been further filtered tc 100 Hz corresponding to the cutoff frequencies used in the original Grand Gulf dynamic analyses. On completion of each test, real time data were compared against the acceptance criteria.

The final data processing and reduction was performed using the software package, REDUCE, Version 1.2.0. REDUCE is a compilation of NUTECH proprietary codes developed for this purpose. The data reduction was performed on a CYBER-730 system.

The software package REDUCE processed the raw digitized data for each channel. The major tasks involved in this process included converting the stored digitized sensor voltages from the binary system into decimal equivalents, demultiplexing the digitized data, and converting the signal from voltage to engineering units. The next step in the data reduction process was to filter the original time-histories and perform a frequency analysis of each data channel. This portion of the data reduction included removal of D.C. offset, digital low pass filtering at 100 Hz, performance of the frequency analysis and calculation of the power spectral densities (PSDs). Acceleration response spectra were developed

for one percent of critical damping for structure mounted accelerometers.

6.2 Data Tape Information

A total of two magnetic tapes were used to store the data recorded from the SRV test program. Table 6.1 provides the reel number, file number and the number of records for each test. Each record contains 3952 8-bit bytes of data. This corresponds to 13 time steps per record when sampling 152 data channels, since each sampled data point is represented by two 8-bit words (e.g., 3952 = 2x152x13).

A data acquisition rate of 1000 samples per second was used for each test. There were approximately 15 seconds of pre-test signal prior to the initial valve actuation for each test.

6.3 Standard Processing Approach

The following processing and data reduction steps were performed on all sensors.

A. Convert the binary digit stream on the data tape to decimal voltage numbers.

B. Demultiplex the data for each channel and convert the signal to engineering units by dividing the voltage values by the sensor's calibration factor.

C. Remove unwanted D.C. offset, transducer bias or thermal drift from the data to obtain only the dynamic portion of the transient.

D. Low pass filter the data at 100 Hz to remove any unwanted high frequency noise.

6.4 Strain Gauge Analysis

The maximum and minimum peak values and the time at which the peak occurs were calculated for each strain gauge. A frequency analysis was performed and the power spectral densities (PSDs) were computed for each strain gauge. Axial and bending stresses were calculated for each group of axially located gauges and used to develop combined stress time-histories.

6.5 Pressure Transducer Analysis

The maximum and minimum values of the filtered pressure time-histories were tabulated for each pressure transducer. PSDs were also developed for each pressure transducer.

6.6 Accelerometer Analysis

In addition to tabulation of maximum and minimum values, PSDs and acceleration response spectra were developed for each sensor from the filtered time-histories. Response spectra were computed at one percent of critical damping. Response spectra envelopes for SVA, CVA and MVA test data for each structure mounted accelerometer were plotted.

The recorded acceleration time-histories for containment mounted accelerometers exhibited some DC offset for the SVA tests. This appears to be a result of charge amplifier saturation, probably caused by a high frequency acoustic type wave induced by the initial air clearing

spike. The effect of this saturation is to induce an offset in the zero datum of the signal which takes approximately one second to recover. As described in Reference 15, Wyle Laboratories has previously investigated the effect of this offset and determined that the signal provides an accurate measure of the containment response. The data reduction program was able to remove most of the DC offset, but in some cases, where the offset was large compared to the magnitude of the recorded data, some traces of the offset remain. The effect of this is most pronounced in the low frequency (less than 20 Hz) parts of the acceleration response spectra.

6.7 Channels Analyzed

The following number of channels were analyzed for the SRV Test Program:

Type	Number
Strain	32 + 20 (for fatigue evaluation)
Pressure	32
Accelerometers	56

In addition, four channels were monitored to provide valve actuation signals. This yields a total of 144 sampled data channels. In order to maintain a record size of 3952 8-bit bytes and 13 time steps per record, a total of 152 sampled channels were needed. Thus, eight blank channels were sampled by the data acquisition system.

Table 6.1

DATA TAPE CONTENTS

Test	Tape Reel No.	File No.	Total No. of Records	Record No. at Which Test Starts	Remarks
SD-1	-	-	-	-	Malfunction of DAS No data collected
MT-10/MT-11	2	1	8011	1090/6280	Actuation of V-10
MT-20/MT-21	2	1	7382	9170/14160	Actuation of V-11
MT-30/MT-31	3	1	7972	1200/6230	Actuation of V-11
MT-70	3	3	6077	950	Actuation of V-2, V-7, V-12 and V-17

NOTE:

1. MT10/MT11 and MT20/MT21 are on a single file. MT20/MT21 is from record 8012 to 15393.

7.0 DISCUSSION OF RESULTS

This section provides a discussion of the pressure, strain, and acceleration results. Each discussion highlights the major observations derived from the data. Comparisons of single (both first and consecutive actuations) and multiple valve actuations are included.

7.1 Suppression Pool Boundary Pressures

As described in Section 3.0, pressure transducers were located on the basemat, the drywell wall and the containment liner. Pressure sensors located within two quencher arm radii ($2r_o$) were used to record peak bubble pressure for each test.

7.1.1 Single Valve First Actuations

All single valve first actuation tests were conducted with the SRVDL water level coincident with the suppression pool surface. In addition, a minimum time interval of two hours between actuation of the same valve (V-11 for MT20 and MT30) was allowed to ensure the SRVDL had cooled to steady state temperature. All tests were conducted without any suppression pool circulation. By using different valves for the single valve first actuation tests, all three tests were conducted as cold pipe first actuations with the same initial conditions for each test.

Typical measured pressure time histories for single valve first actuation tests are given as Figures 7.1 to 7.4. These time histories show the initial trace with a high frequency, high amplitude, pressure characteristic of air bubbles emanating from single columns of holes

which is coincident with the high pressure spike inside the quencher hub. This is followed by lower frequency air clearing of all rows of holes in the quencher arm, and finally by a characteristic high frequency, low amplitude, steam condensation oscillation pressure trace.

Table 7.1 provides a listing of the maximum/minimum measured pressures for all pool mounted pressure transducers. Review of the recorded first actuation data presented in Table 7.1 shows that the maximum positive and negative pressures of +4.63/-5.78 psid were recorded by P12 during test MT10 on quencher V-10. These are much less than the design pressures of +18.2/-7.7 psid.

A frequency analysis for the suppression pool pressure transducer time histories was performed to produce power spectral density functions (PSDs). Predominant frequencies for the initial clearing phenomenon are 30-40 Hz, with typically only one to two cycles, followed by the classically predicted Rayleigh bubble frequencies of 7-12 Hz. In most traces the Rayleigh bubble portion is followed by high frequency, low amplitude, steam condensation oscillation. The fundamental frequency of the steam condensation oscillation is in the range of 70-80 Hz. Typical SVA PSDs are provided as Figures 7.5 and 7.6.

7.1.2 Consecutive Valve Actuations

Three consecutive valve actuations were performed 45 seconds after closure of the first actuation of the same valve. The SRVDL air bleed system, used prior to first

actuations to ensure that the water level in the discharge line was coincident with the suppression pool surface, was not used prior to any CVA. This ensured that the CVAs were performed with water legs representative of the worst possible case during plant operation. Because all SVA/CVA actuations were performed on SRVDLs which had no in-line pressure transducers it is not possible to define the reflood or actual water level prior to a consecutive actuation.

Typical consecutive valve pressure transient time histories are given in Figures 7.7 to 7.10 with typical consecutive valve PSDs provided as Figures 7.11 and 7.12. The typical measured CVA pressure time history has a higher amplitude than the SVAs and a higher frequency content for the major portion of the time history. Also, the initial high frequency air clearing seen during the SVAs is less pronounced for the CVAs. The time history traces shown in Figures 7.7 and 7.8 are close to the GE predicted classical Rayleigh air bubble with typical frequency contents of 10 to 15 Hz. The peak measured CVA pressures were +7.44/-4.47 psid for P6 during MT31 and +7.47/-3.67 psid for P12 during MT11. These are considerably less than the design values of +18.2/-7.7 psid.

7.1.3 Multiple Valve Actuation

One multiple (four) valve test was conducted using quenchers V-2, V-7, V-12 and V-17. Because of previous testing, the SRV associated with quencher V-12 was leaking, such that prior to valve actuation the SRVDL was pressurized with the water level depressed an unknown amount below the suppression pool normal

level. Therefore, the four valve test produced three normal cold pipe single valve first actuation results (V-2, V-7 and V-17) and one hot pipe leaking valve actuation (V-12). Actuation of all four valves was achieved by the use of a temporary switch which permitted simultaneous actuation of the valves with independent closing to minimize reactor water level swell and the possibilities of a scram.

Typical recorded pressure time histories are provided as Figures 7.13 to 7.16 with typical PSDs presented as Figures 7.17 and 7.18. The peak pressures measured during MT70 were +4.06/-2.60 psid for P29. These are less than the expected values of +7.7/-4.4 psid and design values of +10.3/-6.4 psid. The peak measured pressures varied from +3.3/-2.10 psid for pressure transducers close to the leaking V-12 to +4.06/-2.60 psid for pressure transducers close to the other valves. As shown by Figures 7.17 and 7.18 the most noticeable difference between the cold pipe pressure time histories and the leaking valve results is a frequency shift from 7 to 15 Hz. This is similar to the shift seen from the 7-12 Hz for SVA to 10-15 Hz for the CVA and does not represent unexpected behavior or a major frequency shift for the multiple valve case.

7.1.4 Statistical Suppression Pool Pressure Review

More information was obtained from the pressure data by performing a statistical analysis of this data. A value, P, was determined with 95% confidence below which 95% of the normal distribution lies. This 95-95% limit corresponds to the confidence limit applied to previous data used in the development of the CLR pool pressure

methodology, Reference 9. The 95-95% limit is calculated using the following equation:

$$P = \overline{X} + St$$

where

P = 95-95% limit

$\overline{X}$ = measured peak pressure sample mean

S = sample standard deviation

t = one-sided tolerance factor

The tolerance factor is inversely proportional to the number of data points in the sample.

Prior to performing the statistical analysis, data to be included in the sample were individually reviewed and compared to ensure similarity.

The calculation was performed for three different cases: Single valve first actuation (SVA), single valve consecutive actuation (CVA) and multiple valve actuation (MVA). Only data sensors which are expected to sense full quencher discharge pressure, i.e. sensors located within two quencher arm radii ($2r_o$), are included in the sample group. The MVA data was also included in the SVA group, because the MVA can be characterized as three simultaneous SVAs (the results for the leaking V-12 were omitted from the sample). As shown in the Test Matrix, Table 4.1, the MVA test was conducted at a suppression pool temperature 10°F higher than the SVA/CVA tests. The effect of this temperature difference was calculated, using the GESSAR methodology described in Appendix 6D of the Grand Gulf Final Safety Analysis Report, to be less than +0.2 psid. This small differ-

ence is conservative and within the accuracy of the measured data. For the SVA group, 19 data points were available, corresponding to a t factor of 2.41; for the CVA group, 13 data points were available, and the t factor was 2.68; for the MVA group, 9 data points were available, and the t factor was 2.99.

As shown in Tables 7.2, 7.3 and 7.4 the calculated 95-95 pressures are +4.98/-5.51 psid for the SVA, +8.52/-4.62 psid for the CVA and +5.53/-3.55 psid for the MVA. As shown in Table 9.1, the calculated 95-95 pressures for SVA, MVA and CVA are well below the design values for Grand Gulf.

7.2 SRVDL and Quencher Internal Pressures

As described in Section 3.0 pressure transducers were located in the SRVDL, and in the quencher hub and arm for quencher V-12.

Quencher V-12 contains all the line and quencher pressure instrumentation and was only used for two tests (SD1 and MT70). Therefore, the only data available from these sensors is the unfiltered oscillograph records for SD1, no digitized data available due to failure of DAS tape drive, and leaking valve data from MT70. The peak line pressure observed from the unfiltered SD1 data is a high frequency spike with a magnitude of 450 psi, compared to the 550 psi design. No data is available for the quencher hub pressure for SD1 as P23 was not recorded on oscillograph records. The corresponding peak pressure measured for MT70 is 282 psi in the SRVDL

and 242 psi in the quencher hub. These are approximately half of the design value of 550 psi.

7.3 Strain Data

Strain gauge locations are described in Table 3.2 and Figures 3.4 and 3.5. The measured strain data have been reduced and tabulated in Table 7.5 which provides a listing of peak measured strain for each test along with the expected value for each gauge. Representative strain time-history plots are presented in Figures 7.9 through 7.21.

7.3.1 Quencher Support Strains

Strain gauges were mounted on the V-12 quencher support to measure the strains during discharge of V-12 and also induced loads by discharge of an adjacent quencher (V-11). During the actual tests V-12 was used for two tests. For test SD1 the DAS malfunctioned and no data was collected and MT70 represented a leaking valve condition.

Figure 7.21 provides a typical strain time history for SG6, mounted on the horizontal quencher support, during discharge of V-12. The quencher support strains are small compared to the expected test values. The peak measured strain for the vertical support is 20)in/in. The peak measured strain for the cantilever support is 22)in/in compared to an expected test value of 98)in/in. For tests involving quenchers V-10 or V-11 no distinct strains related to discharge loads can be defined from the general background noise.

Strain gauge SG7 measured a well defined strain time history corresponding to the shape of the pressure waves. This is not observed for the other gauges mounted on the quencher support nor any of the other submerged structure strain gauges. Therefore, it is reasonable to assume that SG7 has become partially detached from the support and is providing incorrect measurements. Therefore, SG7 measured results are not used in this report.

The measured strain data was used to determine the maximum axial and principal stresses in the quencher support. Because of failure of SG9 principal stresses were only calculated for the vertical portion of the quencher support. The maximum shear stress was 280 psi during blowdown of quencher V-12. The maximum principal stress was 510 psi compared to the predicted value of 1035 psi. The maximum axial stress in the cantilever portion of the support was 645 psi.

7.3.2 Submerged Piping Strains

Figure 7.20 provides a strain time history for a pipe mounted strain gauge. This time history is typical, for all tests, for gauges mounted on the RCIC turbine exhaust line (adjacent to V-12) and those mounted on the RHR A pump test line (midway between V-11 and V-12). Strain gauges mounted on these two lines measured a maximum strain of 12)in/in compared to an expected value of 56)in/in. The peak calculated axial stress was 260 psi. In general, regardless of which quencher was discharged, the measured strain is always small when compared to the expected value.

7.3.3 Containment Liner Strains

Figure 7.19 shows a typical strain time history for a base liner gauge. Strain gauges mounted on the containment base liner measured the highest recorded strains during the testing. Gauges SG11 and SG12 located midway between V-10 and V-11 measured a maximum strain of 50)in/in. This is 5% of the yield strain used for the design of the liner. Gauges mounted on other portions of the base liner and containment vessel wall liner recorded smaller strains.

Based on the recorded strain data collected, the strains induced by SRV discharge loads are very small and are well within the expected values.

7.4 Accelerometer Data

A description of accelerometer locations is provided in Section 3 and Tables 3.3, 3.4, and Figures 3.7 through 3.12.

Table 7.6 provides a tabulation of the peak measured acceleration for each accelerometer, for each test. In addition, the table provides average SVA and CVA accelerations, and design and expected values. The structural acceleration design values are taken from the Grand Gulf design response spectra, and are equal to the zero period acceleration (zpa) for the single valve consecutive actuation (SRV_{one}) case. The accelerations for accelerometers mounted on valves and the hydrogen recombiner are taken directly from the appropriate analyses. The expected values are 80% of the design values. This ratio was selected based on the ratio of peak predicted pool pressure from test to design

conditions. Figures 7.22 through 7.24 give representative acceleration time-history plots for accelerometer A5 for a SVA, CVA and MVA test. Envelope response spectra for the SVA, CVA and MVA tests at 1% of critical damping for each structure mounted accelerometer on the containment, RPV pedestal, drywell and Auxiliary Building are presented in Section 8.

A review of Table 7.6 shows that the majority of peak measured accelerations are considerably less than 50% of the predicted value. The measured equipment responses (A29 to A52) are generally an order of magnitude less than the predicted values and show that the high frequency content of the SRV time histories are greatly attenuated by the attached piping systems and floors.

Based on the very low levels of acceleration measured during SD1, many of the accelerometers were set to maximum sensitivity to try and read the very small induced vibrations. The result of this was that the measured signal is in many cases equal to, or less than, the background noise. In general, as can be seen from Table 7.6, the measured acceleration is only a small fraction of the expected value. In compiling Table 7.6, a number of recorded accelerometer time histories which include some anomalies such as D.C. offset, wild points, or excessive background noise, were included when resulting values were small or did not affect the final conclusions. This happened most frequently for accelerometers measuring very small magnitudes where 60 Hz noise sometimes dominated the data.

As noted above some of the measured acceleration time histories contained anomalies such as D.C. offset, wild points and an offset due to charge amplifier satura-

tion. The data reduction program, REDUCE, was used to remove such anomalies from the measured acceleration time histories for A4, A25, and A26, for all SVA tests, and from A7 and A8, for all tests. Other anomalies in the measured acceleration time histories were:

- A2 is a vertical accelerometer located on the containment base mat at elevation 93'-0" and azimuth 312° at radius 65'-0", outside the suppression pool. This accelerometer recorded apparent maximum vertical accelerations an order of magnitude higher than those measured by all other vertical accelerometers on the containment, drywell, RPV pedestal and equipment. Therefore, it is concluded that this accelerometer, or the signal conditioning, is malfunctioning and A2 results have been omitted from Table 7.6 and the calculated spectra.

- Accelerometers All and A12 were mounted at mid span on the bottom flange of the polar crane rail girder at elevation 237'-0". Accelerometer All measured radial response and A12 the vertical response. Figure 7.25 shows a typical measured acceleration time history for both accelerometers with a clear ringing type response. The radial response for All is approximately an order of magnitude higher than the containment response at elevation 145'-7" (A7, A9, A10) and at the top of the dome (elevation 302'-3", A14). This is a local response and has no effect on the containment or polar crane design. This is demonstrated by the very low accelerations measured at mid-span of the polar crane girder (A29 to A31) where the peak measured acceleration for all tests was 0.02g.

the containment response at elevation 145'-7" (A7, A9, A10) and at the top of the dome (elevation 302'-3", A14). This is a local response and has no effect on the containment or polar crane design. This is demonstrated by the very low accelerations measured at mid-span of the polar crane girder (A29 to A31) where the peak measured acceleration for all tests was 0.02g.

Table 7.1

MEASURED PEAK PRESSURE DATA (PSID)

Sensor	SVA Tests			MVA Test	CVA Tests		
	MT10	MT20	MT30	MT70	MT11	MT21	MT31
P1	+0.86/-0.41	+1.29/-1.51	+0.93/-1.29	+2.20/-2.35	+0.75/-0.59	+2.32/-1.68	+2.65/-2.04
P2	+0.88/-1.00	+1.89/-1.87	+1.30/-1.60	+1.46/-1.11	+0.98/-0.82	+2.23/-1.42	-2.46/-1.85
P3	+1.13/-0.80	+1.70/-1.76	+1.40/-1.59	+1.52/-1.48	+1.15/-0.70	+1.76/-1.24	+1.92/-1.57
P4	+0.51/-0.47	+0.97/-0.98	+1.14/-0.83	+0.55/-0.64	+0.54/-0.62	+1.60/-1.10	+2.07/-1.73
P5	+0.97/-0.71	+1.94/-2.10	+2.15/-2.04	+0.80/-0.89	+1.27/-0.76	+3.42/-2.63	+4.49/-3.29
P6	+1.20/-1.30	+3.00/-3.70	+3.08/-2.60	+1.07/-0.81	+1.68/-1.29	+5.48/-3.35	+7.44/-4.47
P7	+1.53/-1.63	+2.97/-3.26	+3.24/-2.58	+1.28/-1.05	+2.29/-1.10	+3.69/-3.27	+4.99/-3.68
P8	+0.76/-1.17	+2.47/-2.54	+2.58/-2.20	+1.59/-1.20	+1.33/-0.97	+3.68/-2.71	+4.27/-3.12
P9	+2.45/-2.28	+3.68/-3.23	+3.31/-2.87	+0.14/-0.96	+2.83/-1.70	+2.68/-2.00	+3.01/-2.47
P10	+1.58/-1.59	+2.25/-2.09	+1.82/-1.94	+1.08/-0.73	+1.70/-1.31	+2.18/-1.75	+2.58/-1.92
P11	+0.86/-0.46	+0.77/-0.85	+0.60/-0.94	+0.44/-0.33	+0.86/-0.42	+0.89/-0.74	+0.96/-1.02
P12	+4.63/-5.78	+4.12/-4.20	+4.18/-4.89	+1.48/-1.14	+7.47/-3.67	+4.56/-2.81	+5.17/-2.98
P13	+3.10/-3.30	+1.49/-1.58	+1.05/-1.49	+1.02/-0.99	+5.50/-3.50	+1.85/-1.33	+2.27/-1.53
P14	+3.34/-2.87	+2.04/-1.67	+1.63/-1.64	+1.15/-0.97	+3.28/-2.76	+1.53/-0.96	+1.91/-1.28
P15	+2.49/-2.26	+2.03/-1.54	+1.79/-1.52	+1.02/-1.02	+2.57/-1.74	+1.37/-1.14	+1.52/-1.22
P16	+1.42/-1.48	+1.08/-0.73	+0.93/-0.71	+1.30/-0.65	+1.70/-1.26	+0.70/-0.37	+0.79/-0.55
P17	+2.02/-1.66	+1.35/-1.15	+1.17/-1.20	+1.67/-1.07	+2.04/-1.15	+0.52/-0.36	+0.66/-0.60
P18	+0.36/-0.40	+0.05/-0.16	+0.10/-0.16	+1.55/-1.50	+0.29/-0.30	+0.15/-0.09	+0.14/-0.12
P19	+0.53/-0.34	+0.27/-0.38	+0.25/-0.41	+2.75/-2.40	+0.44/-0.28	+0.09/-0.18	+0.14/-0.21
P20	+0.09/-0.12	+0.14/-0.15	+0.09/-0.16	+2.77/-1.52	+0.08/-0.04	+0.20/-0.10	+0.12/-0.12
P26	+0.87/-0.64	+1.34/-1.51	+0.72/-0.89	+0.70/-0.67	+0.98/-1.07	+1.43/-1.30	+1.49/-1.66
P27	+1.09/-0.97	+1.86/-2.14	+1.28/-1.14	+0.88/-0.80	+1.25/-1.85	+2.10/-1.75	+2.33/-2.26
P29	+0.15/-0.10	+0.10/-0.18	+0.11/-0.12	+4.06/-2.60	+0.11/-0.05	+0.20/-0.09	+0.14/-0.18
P30	+0.82/-0.45	+0.31/-0.47	+0.40/-0.49	+3.32/-2.10	+0.54/-0.32	+0.19/-0.14	+0.24/-0.19
P31	+0.10/-0.56	+0.13/-0.15	+0.11/-0.14	+3.59/-1.94	+0.06/-0.05	+0.16/-0.09	+0.13/-0.15
P32	+0.12/-0.10	+0.11/-0.20	+0.11/-0.13	+3.56/-2.20	+0.07/-0.10	+0.14/-0.08	+0.13/-0.14
Peak Pressures	+4.63 -5.78	+4.12 -4.20	+4.18 -4.89	+4.06 -2.60	+7.47 -3.67	+5.48 -3.35	+7.44 -4.47

Table 7.2

SVA 95-95 PRESSURES (PSID)

Test	Sensor	Measured Pressure	
		Positive	Negative
MT10	P12	+4.63	-5.78
	P13	+3.10	-3.30
	P14	+3.34	-2.87
MT20	P5	+1.94	-2.10
	P6	+3.00	-3.70
	P7	+2.97	-3.26
	P8	+2.47	-2.54
	P12	+4.12	-4.20
MT30	P5	+2.15	-2.04
	P6	+3.80	-2.06
	P7	+3.24	-2.58
	P8	+2.58	-2.20
	P12	+4.18	-4.89
MT70	P19	+2.75	-2.40
	P20	+2.77	-1.52
	P29	+4.06	-2.60
	P30	+3.32	-2.10
	P31	+3.59	-1.94
	P32	+3.56	-2.20

Positive Pressure

$\overline{X} = 3.24$

$S = 0.72$

Negative Pressure

$\overline{X} = -2.88$

$S = -1.09$

$t_{19} = 2.41$

95-95 pressure = +4.98 psid

95-95 pressure = -5.51 psid

Table 7.3

CVA 95-95 PRESSURES (PSID)

Test	Sensor	Measured Pressure	
		Positive	Negative
MT11	P12	+7.47	-3.67
	P13	+5.50	-3.50
	P14	+3.28	-2.76
MT21	P5	+3.42	-2.63
	P6	+5.48	-3.35
	P7	+3.69	-3.27
	P8	+3.68	-2.71
	P12	+4.56	-2.81
MT31	P5	+4.49	-3.29
	P6	+7.44	-4.47
	P7	+4.99	-3.68
	P8	+4.27	-3.12
	P12	+5.17	-2.98

Positive Pressure

$\overline{X} = 4.88$

$S = 1.36$

Negative Pressure

$\overline{X} = -3.25$

$S = -0.51$

$t_{13} = 2.68$

95-95 pressure = +8.52 psid

95-95 pressure = -4.62 psid

Table 7.4

MVA 95-95 PRESSURES (PSID)

Test	Sensor	Measured Pressure	
		Positive	Negative
MT70	P1	+2.20	-2.35
	P2	+1.46	-1.11
	P8	+1.59	-1.20
	P19	+2.75	-2.40
	P20	+2.77	-1.52
	P29	+4.06	-2.60
	P30	+3.32	-2.10
	P31	+3.59	-1.94
	P32	+3.56	-2.20

Positive Pressure

$\overline{X} = 2.81$

$S = 0.91$

Negative Pressure

$\overline{X} = -1.94$

$S = -0.54$

$t_9 = 2.99$

95-95 pressure = +5.53 psid

95-95 pressure = -3.55 psid

Table 7.5

PEAK STRAIN DATA (μin/in)

Sensor	SVA Tests			MVA Test	CVA Tests			Expected
	MT10	MT20	MT30	MT70	MT11	MT21	MT31	Value
S1	2	4	3	16	2	5	5	(1)
S2	13	10	11	8	17	10	9	(1)
S3	18	12	11	7	15	8	11	(1)
S4	31	20	20	10	34	15	22	(1)
S5	3	2	3	12	2	4	5	98
S6	1	3	3	17	2	3	6	98
S8	3	4	2	22	2	3	3	98
S10	2	4	2	9	2	3	4	(2)
S11	12	9	9	8	11	13	12	(1)
S12	43	50	41	18	42	32	31	(1)
S13	4	3	3	7	4	3	5	(1)
S14	5	5	5	5	3	4	5	(1)
S16	1	3	3	9	2	6	12	56
S17	3	4	5	5	3	6	12	56
S18	3	4	4	6	2	3	5	56
S19	2	4	4	5	2	3	5	44
S20	1	3	3	8	2	3	3	44
S21	4	5	5	5	5	4	4	44
S22	1	5	4	7	2	3	4	54
S23	2	3	3	5	2	4	3	(2)
S24	1	3	3	8	1	3	4	44
S25	4	4	3	5	3	4	5	(1)
S26	1	3	2	7	2	5	4	(1)
S27	3	4	4	5	3	5	4	(1)
S28	3	5	5	7	2	4	7	(1)
S29	4	5	5	7	3	4	6	(2)
S30	2	3	4	19	3	3	7	22
S31	9	7	8	10	6	5	7	45
S32	3	4	5	14	4	4	6	45
S33	5	7	4	20	3	5	5	45
S34	4	4	5	14	5	6	4	45

Notes: 1. Expected values not calculated, allowable strain is 980 μin/in.

2. Values not calculated - part of strain rosettes or insufficient information available.

Table 7.6

PEAK MEASURED ACCELERATIONS (g)

Sensor	SVA Tests			MVA Test	CVA Tests			Mean Value		SVA/CVA Design Value	SVA/CVA Predicted Value
	MT10	MT20	MT30	MT70	MT11	MT21	MT31	SVA	CVA		
A1	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.04	0.03
A3	0.05	0.09	0.08	0.09	0.05	0.05	0.06	0.07	0.05	0.35	0.28
A4	0.02	0.03	0.02	0.03	0.01	0.02	0.02	0.02	0.02	0.09	0.07
A5	0.05	0.03	0.05	0.17	0.04	0.01	0.03	0.04	0.03	0.35	0.28
A6	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.35	0.28
A7	0.02	0.03	0.02	0.05	0.03	0.05	0.07	0.02	0.05	0.20	0.16
A8	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.02	0.03	0.05	0.04
A9	0.03	0.04	0.03	0.03	0.03	0.01	0.01	0.03	0.02	0.20	0.16
A10	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.20	0.16
A11	0.14	0.10	0.12	0.19	0.12	0.05	0.05	0.12	0.07	N/A	N/A
A12	0.04	0.05	0.04	0.11	0.04	0.02	0.02	0.04	0.03	N/A	N/A
A13	0.02	0.02	0.02	0.06	0.02	0.02	0.02	0.02	0.02	0.09	0.07
A14	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.08	0.06
A15	0.04	0.04	0.06	0.05	0.05	0.03	0.02	0.05	0.03	0.16	0.13
A16	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02
A17	0.08	0.05	0.04	0.06	0.03	0.02	0.01	0.06	0.02	0.16	0.13
A18	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.16	0.13
A19	0.002	0.002	0.002	0.005	0.002	0.002	0.002	0.002	0.002	0.11	0.09
A20	0.004	0.004	0.004	0.005	0.004	0.004	0.004	0.004	0.004	0.03	0.02
A21	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.02
A22	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.02
A23	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.02
A24	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.02
A25	0.004	0.005	0.003	0.004	0.002	0.002	0.003	0.004	0.002	0.02	0.02
A26	0.004	0.002	0.003	0.002	0.001	0.001	0.002	0.003	0.001	0.02	0.02
A27	0.003	0.002	0.003	0.005	0.002	0.005	0.004	0.003	0.004	0.02	0.02
A28	0.004	0.004	0.004	0.003	0.002	0.005	0.002	0.004	0.003	0.02	0.02
A29	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	N/A	N/A

Table 7.6

PEAK MEASURED ACCELERATIONS (g)

(Concluded)

Sensor	SVA Tests			MVA Test	CVA Tests			Mean Value		SVA/CVA Design Value	SVA/CVA Predicted Value
	MT10	MT20	MT30	MT70	MT11	MT21	MT31	SVA	CVA		
A30	0.001	0.001	0.001	0.002	0.00	0.001	0.001	0.001	0.001	N/A	N/A
A31	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	N/A	N/A
A32	0.01	0.03	0.02	0.02	0.01	0.01	0.01	0.02	0.01	N/A	N/A
A33	0.02	0.02	0.02	0.03	0.02	0.01	0.01	0.02	0.01	N/A	N/A
A34	0.01	0.02	0.02	0.03	0.01	0.01	0.01	0.02	0.01	N.A	N/A
A35	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.03	0.02	N/A	N/A
A36	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	N/A	N/A
A37	0.03	0.06	0.05	0.06	0.03	0.03	0.04	0.05	0.03	N/A	N/A
A38	0.03	0.02	0.03	0.03	0.02	0.02	0.02	0.03	0.02	0.36	0.29
A39	0.02	0.02	0.02	0.04	0.01	0.02	0.03	0.02	0.02	0.41	0.33
A40	0.004	0.005	0.004	0.005	0.005	0.005	0.007	0.004	0.005	0.25	0.20
A41	0.03	0.03	0.04	0.09	0.04	0.04	0.04	0.03	0.04	N/A	N/A
A42	0.07	0.06	0.04	0.22	0.06	0.04	0.06	0.06	0.05	1.21	0.97
A43	0.06	0.07	0.06	0.09	0.06	0.07	0.06	0.06	0.06	1.59	1.27
A44	0.03	0.03	0.04	0.03	0.03	0.04	0.04	0.03	0.04	2.00	1.60
A45	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	2.01	1.60
A46	0.07	0.05	0.04	0.04	0.07	0.05	0.05	0.05	0.06	2.81	2.25
A47	0.30	0.50	0.45	0.38	0.30	0.13	0.14	0.42	0.19	2.01	1.60
A49	0.01	0.02	0.02	0.02	0.01	0.01	0.03	0.02	0.02	1.97	1.56
A50	0.05	0.04	0.01	0.02	0.04	0.03	0.01	0.03	0.03	2.52	1.80
A51	0.13	0.10	0.03	0.06	0.13	0.06	0.03	0.09	0.07	1.20	0.96
A52	0.16	0.18	0.04	0.06	0.15	0.08	0.03	0.13	0.09	2.84	2.27
A53	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	N/A	N/A
A54	0.01	0.02	0.01	0.02	0.01	0.01	0.02	0.01	0.01	N/A	N/A
A55	0.01	0.01	0.01	0.005	0.01	0.003	0.004	0.01	0.01	N/A	N/A
A56	0.004	0.005	0.004	0.003	0.003	0.002	0.003	0.004	0.003	N/A	N/A

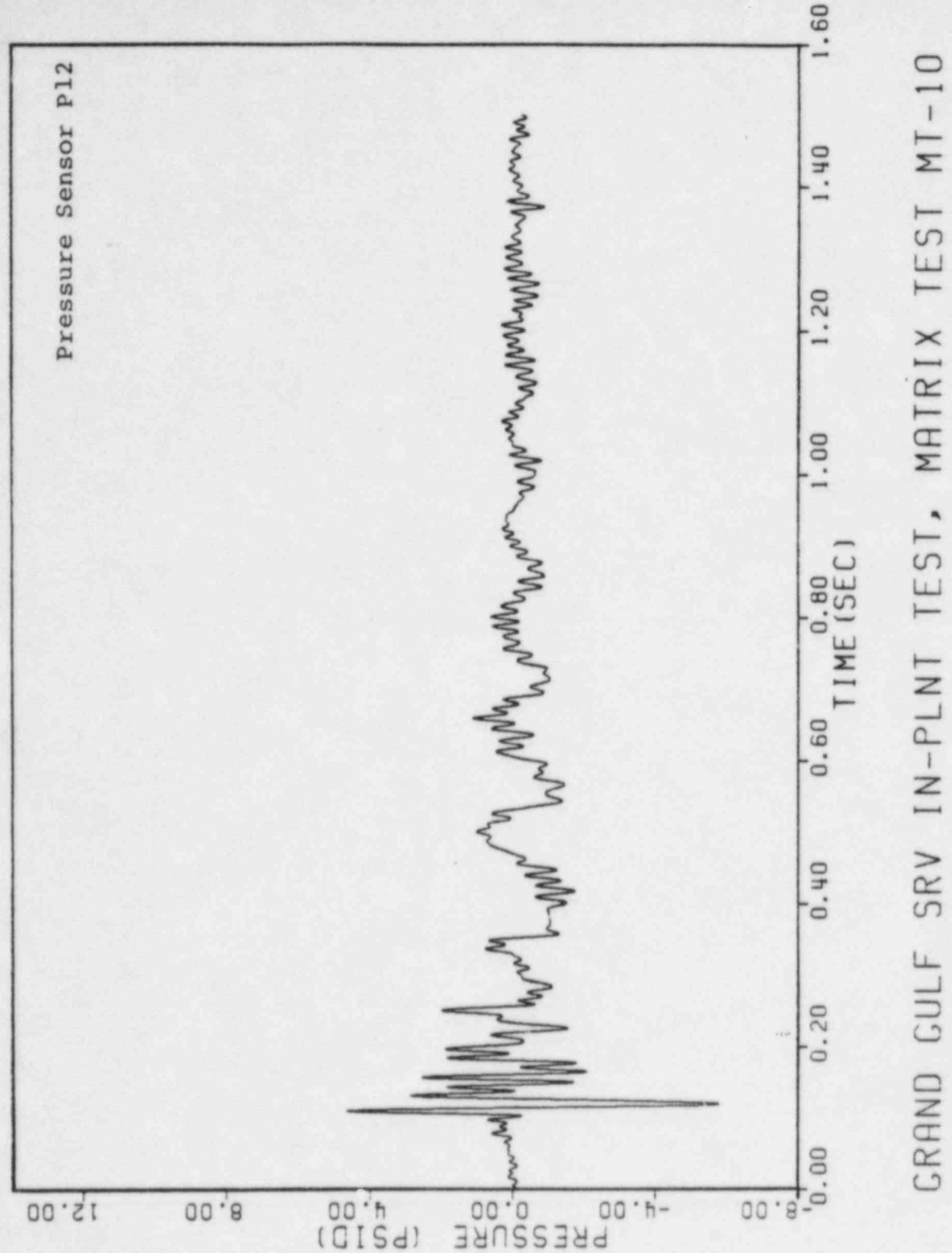


Figure 7.1

TYPICAL SVA PRESSURE TIME HISTORY

nutech ENGINEERS

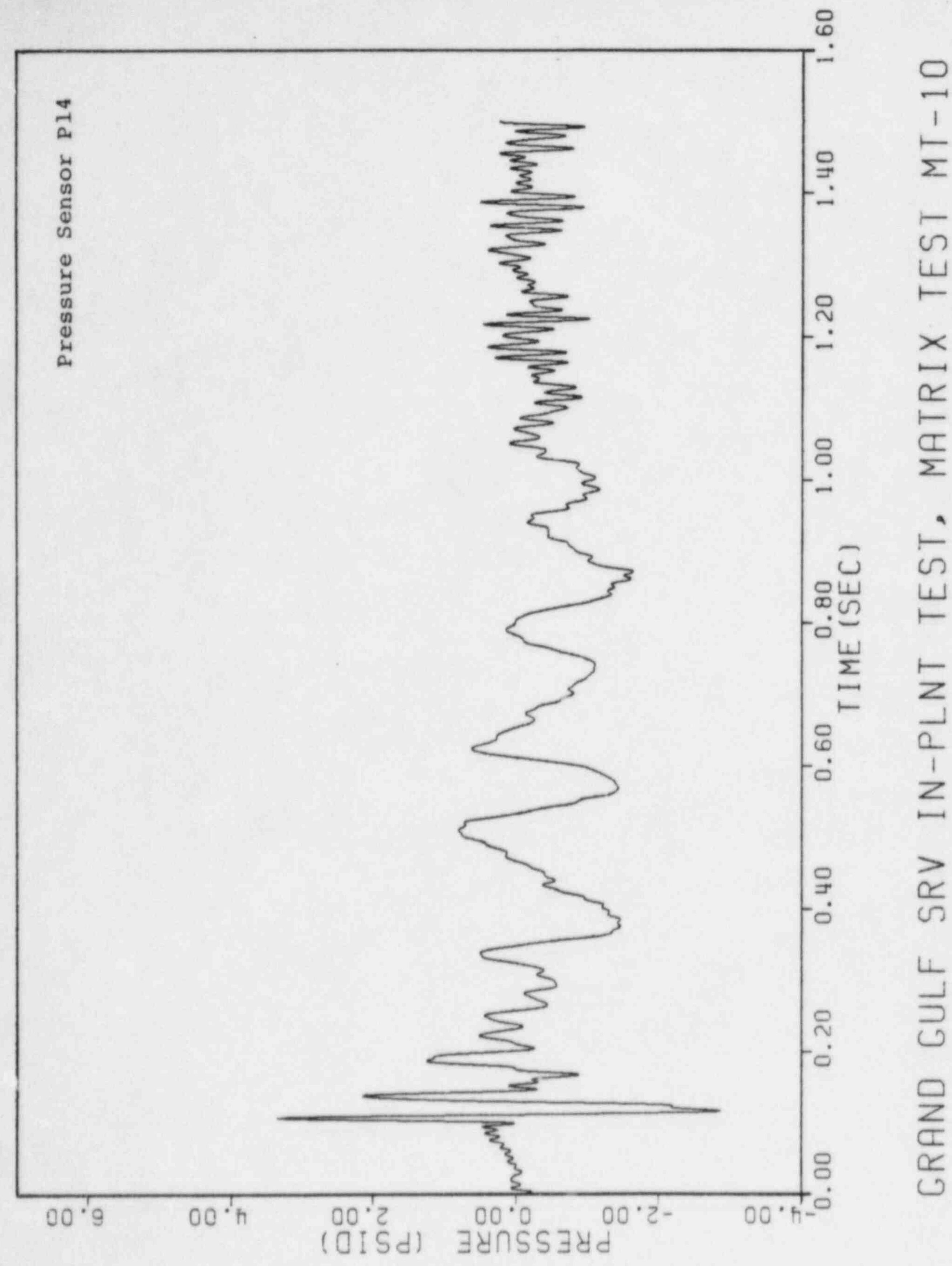


Figure 7.2

TYPICAL SVA PRESSURE TIME HISTORY

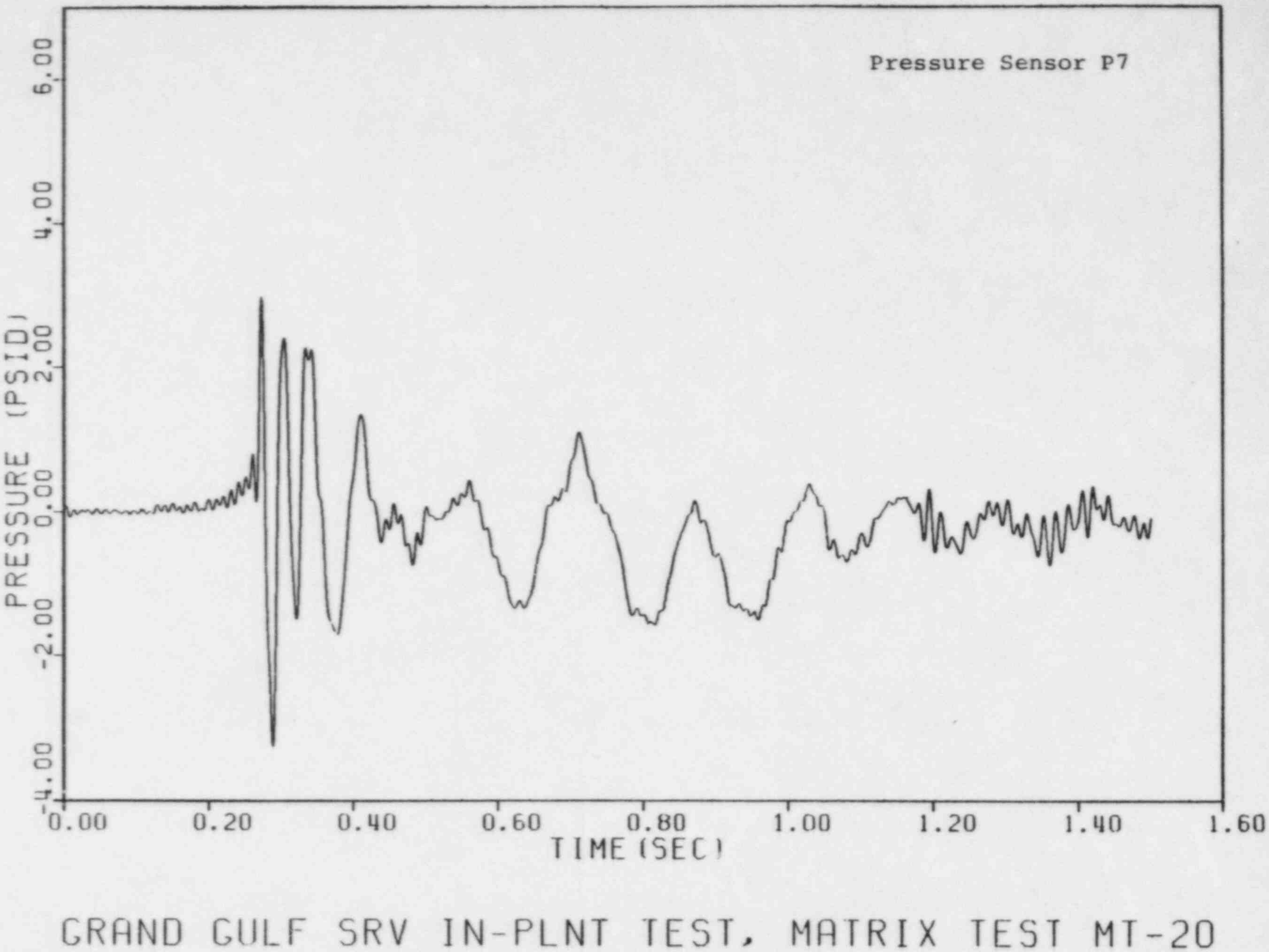


Figure 7.3

TYPICAL SVA PRESSURE TIME HISTORY

nutech ENGINEERS

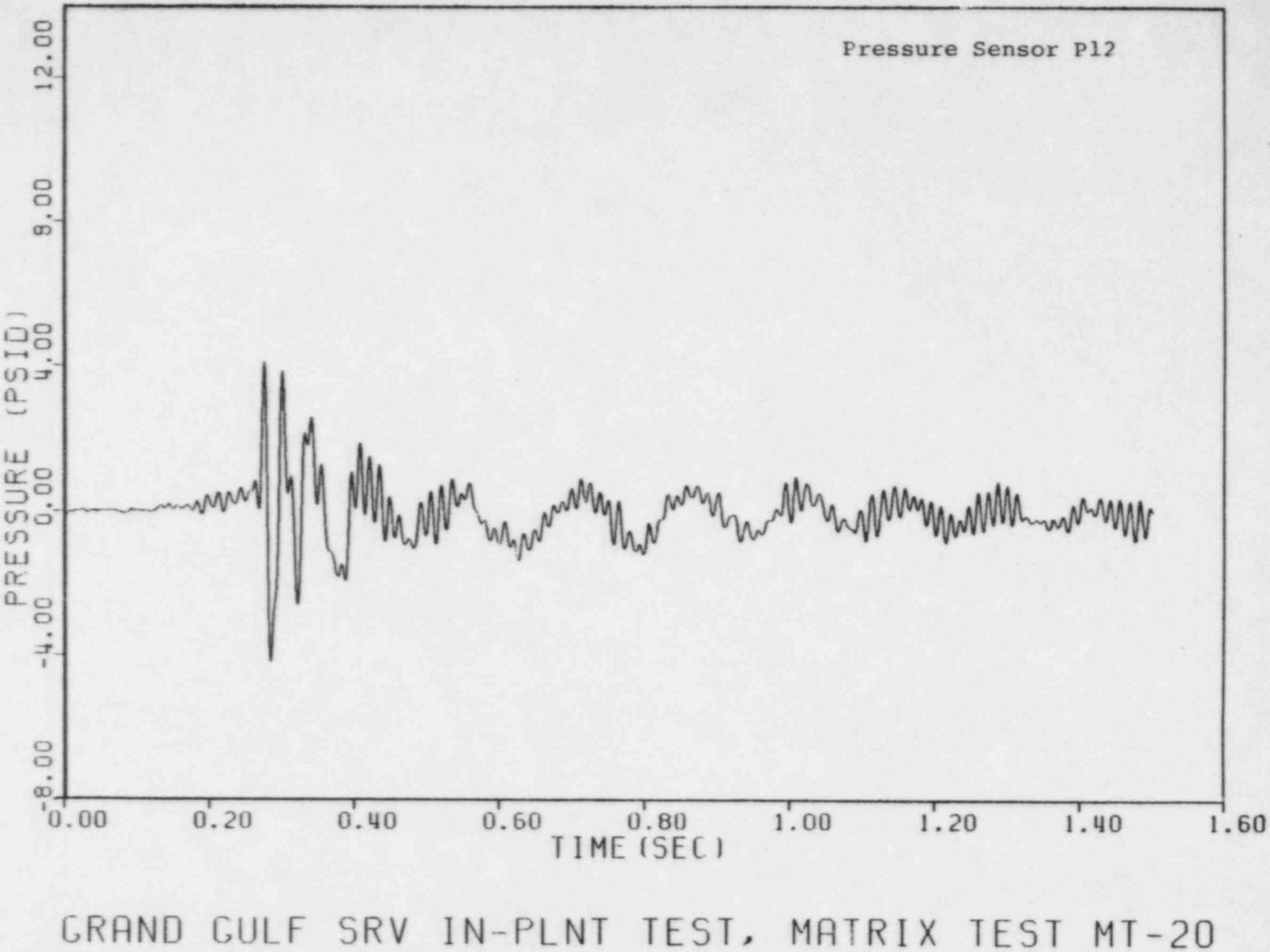


Figure 7.4

TYPICAL SVA PRESSURE TIME HISTORY

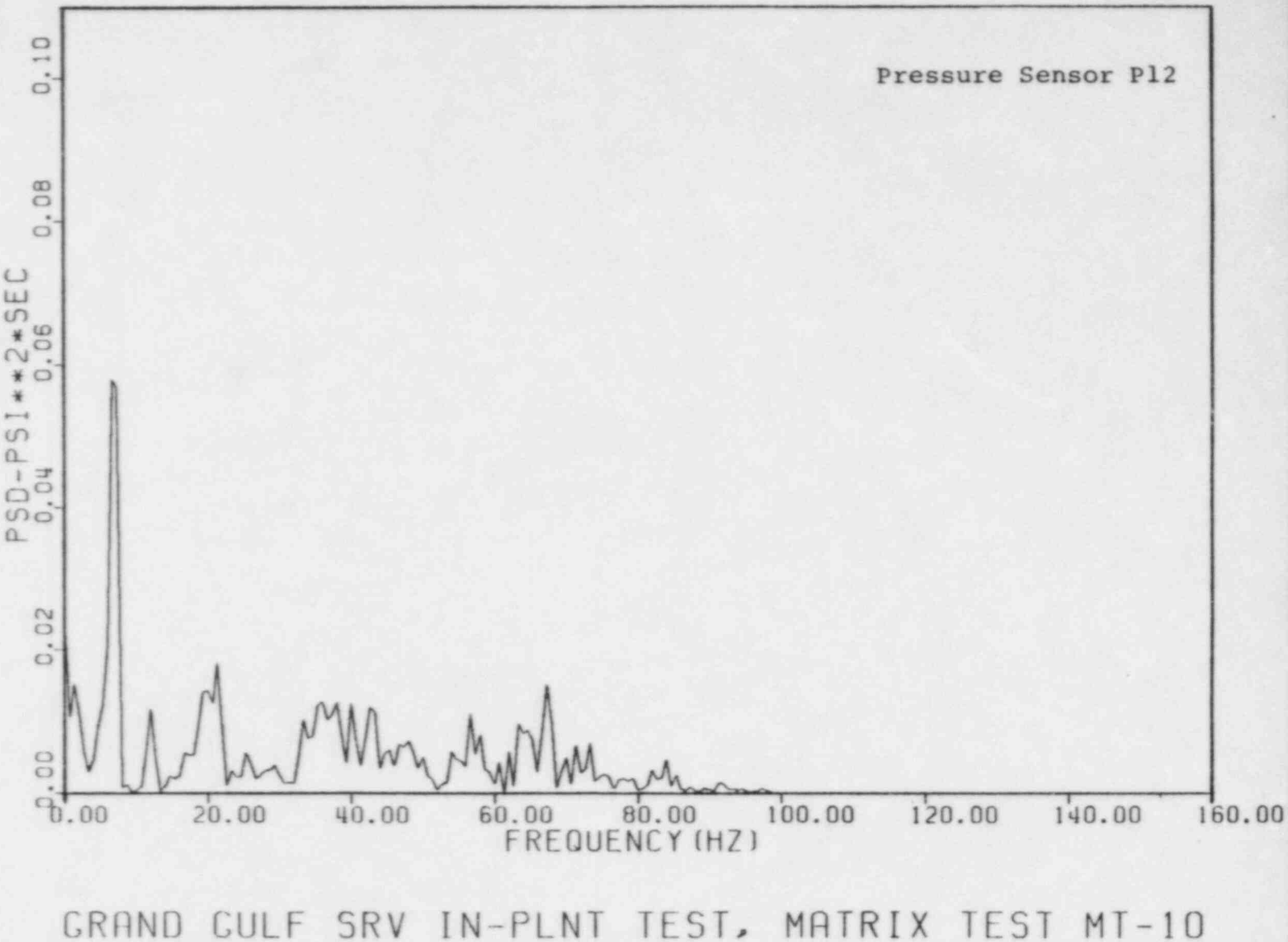


Figure 7.5

TYPICAL SVA PRESSURE PSD

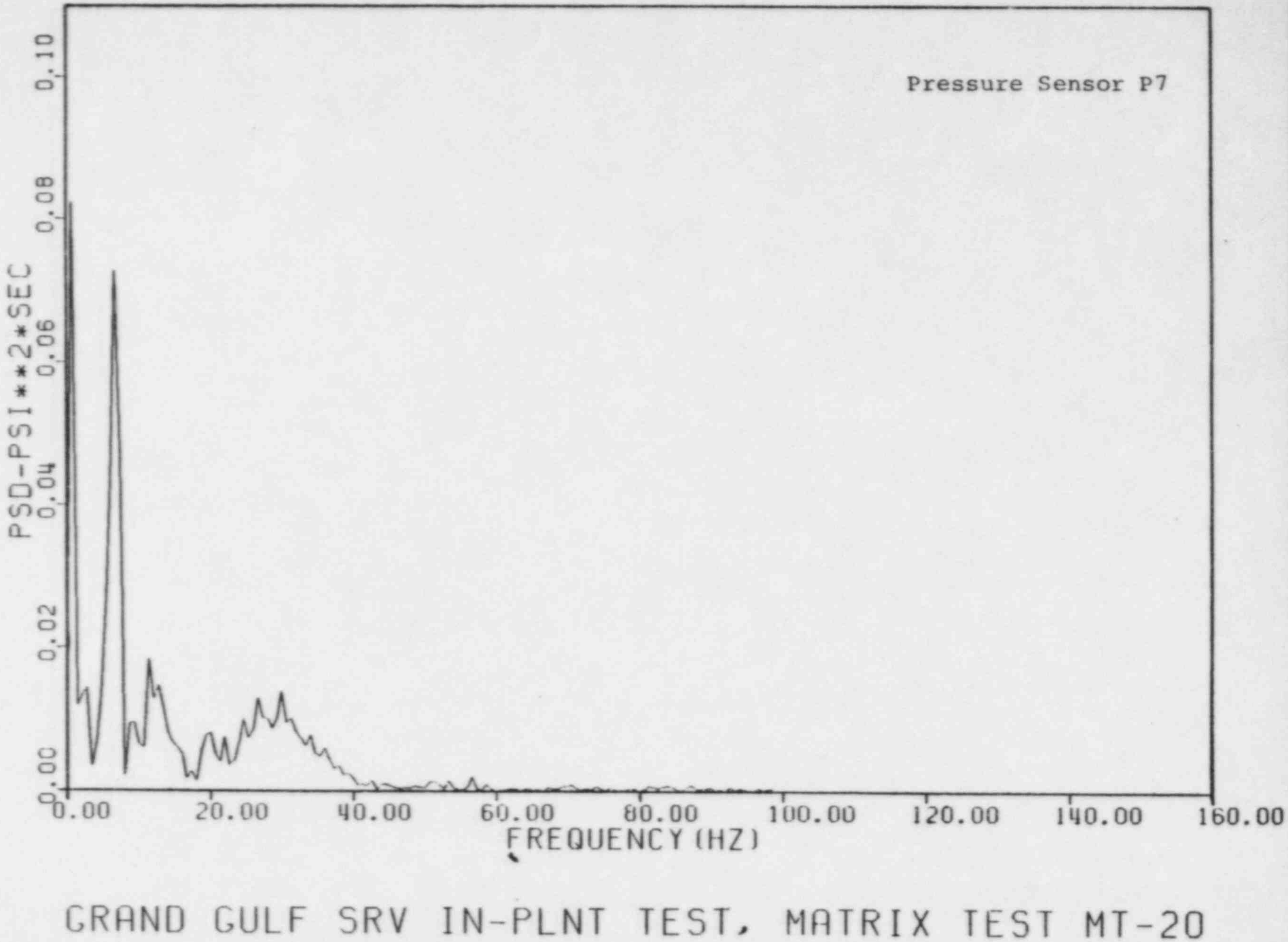


Figure 7.6
TYPICAL SVA PRESSURE PSD

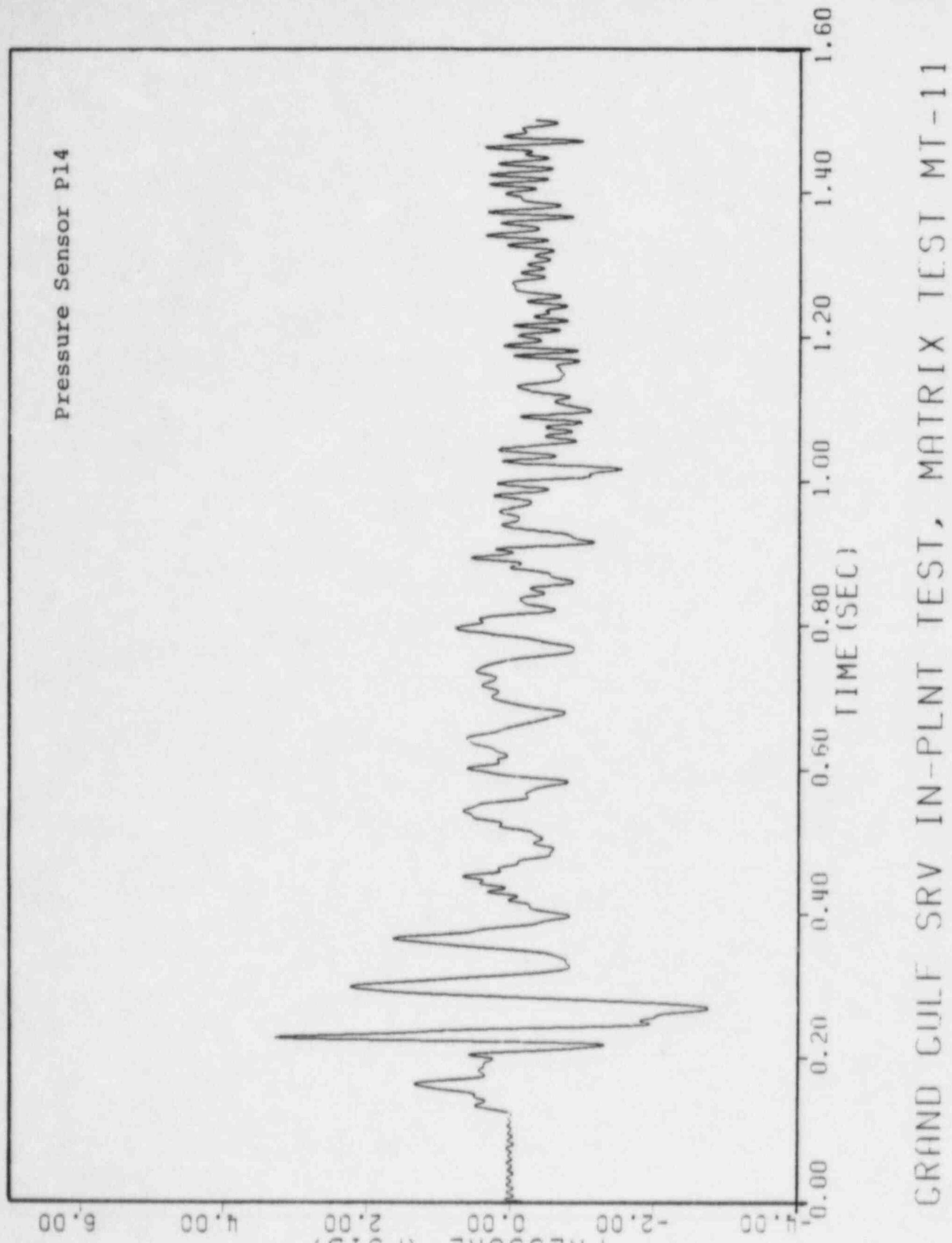
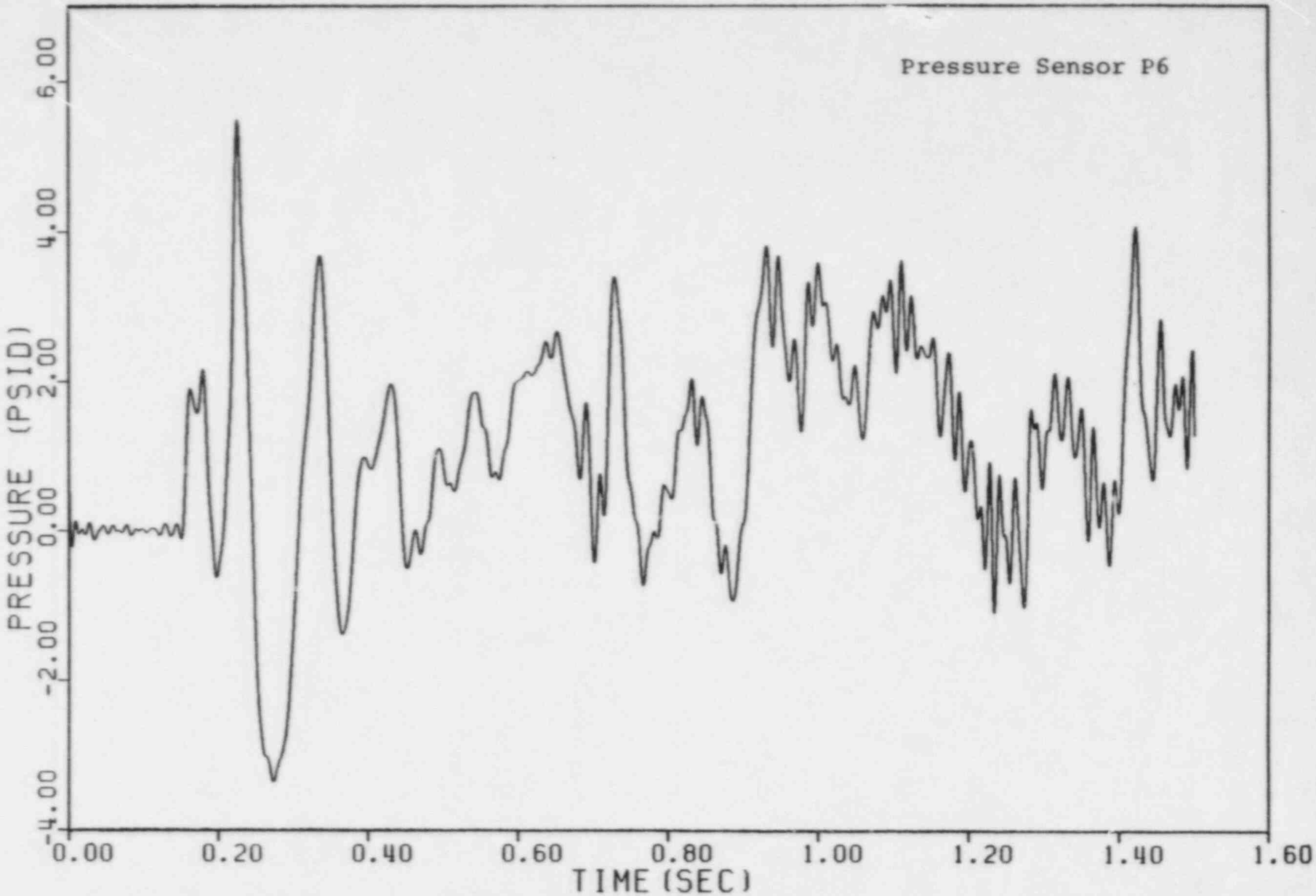


Figure 7.7

TYPICAL CVA PRESSURE TIME HISTORY



GRAND GULF SRV IN-PLNT TEST, MATRIX TEST MT-21

Figure 7.8

TYPICAL CVA PRESSURE TIME HISTORY

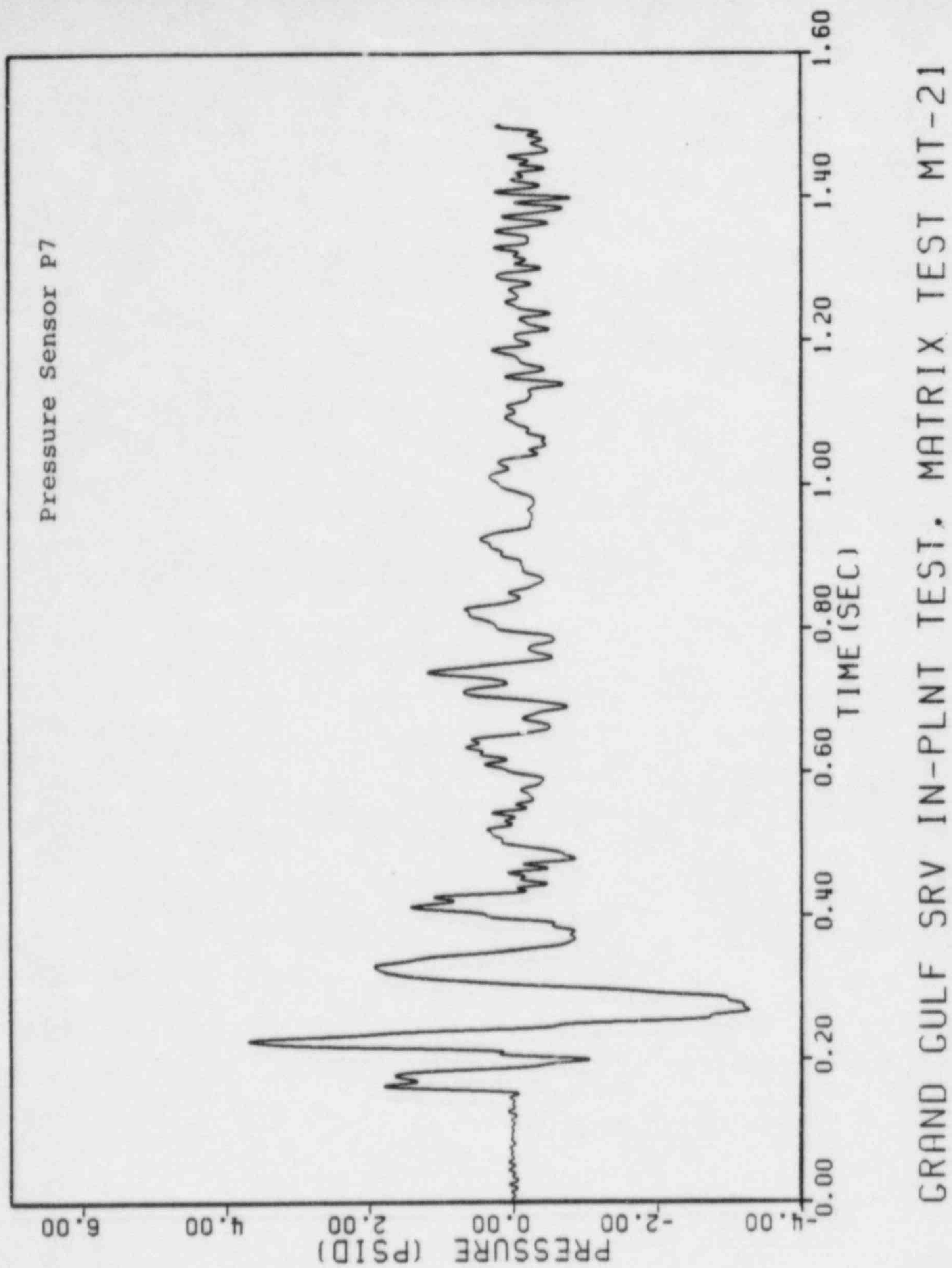


Figure 7.9

TYPICAL CVA PRESSURE TIME HISTORY

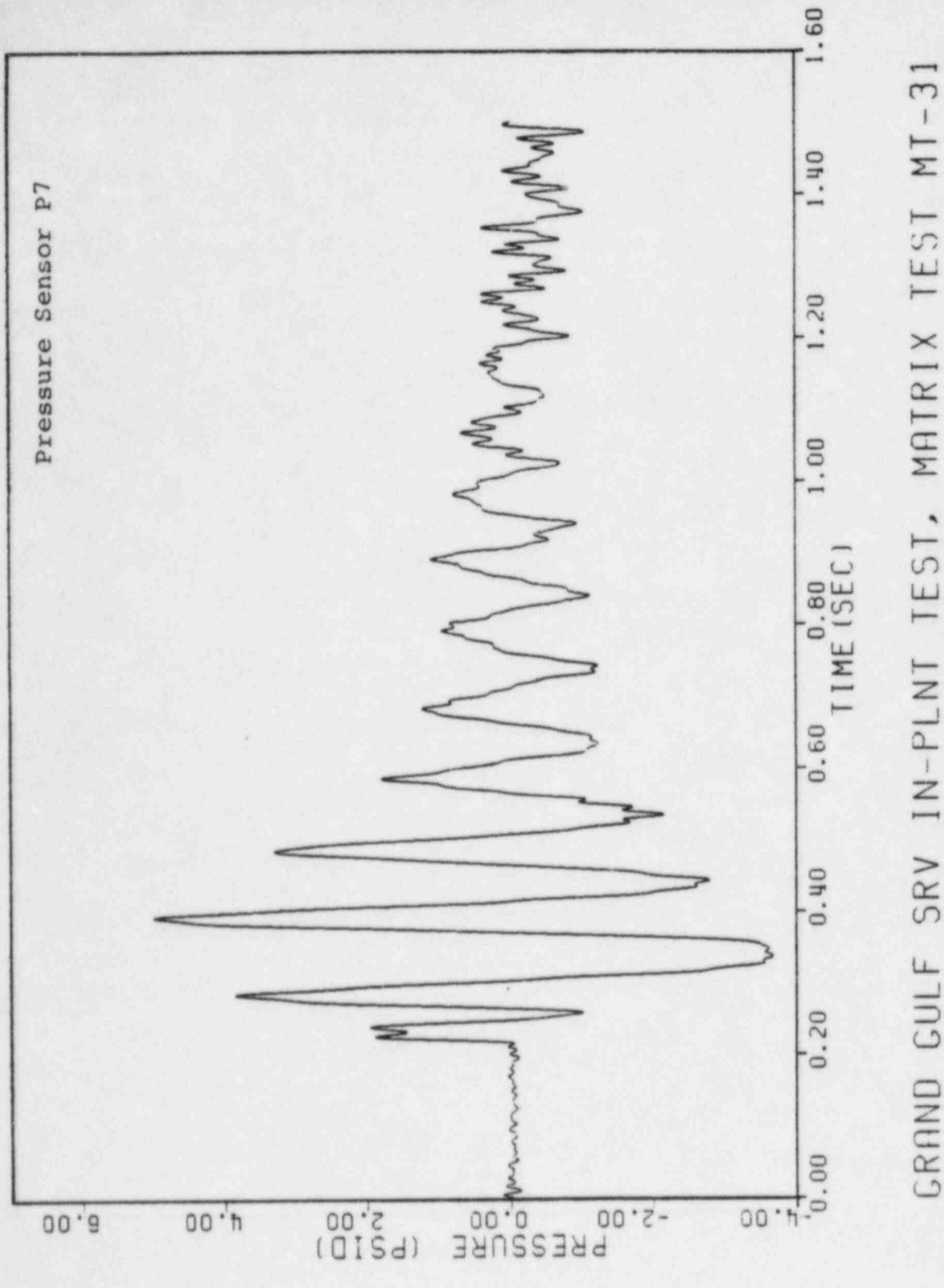


Figure 7.10

TYPICAL CVA PRESSURE TIME HISTORY

MPL-01-220
Revision 0

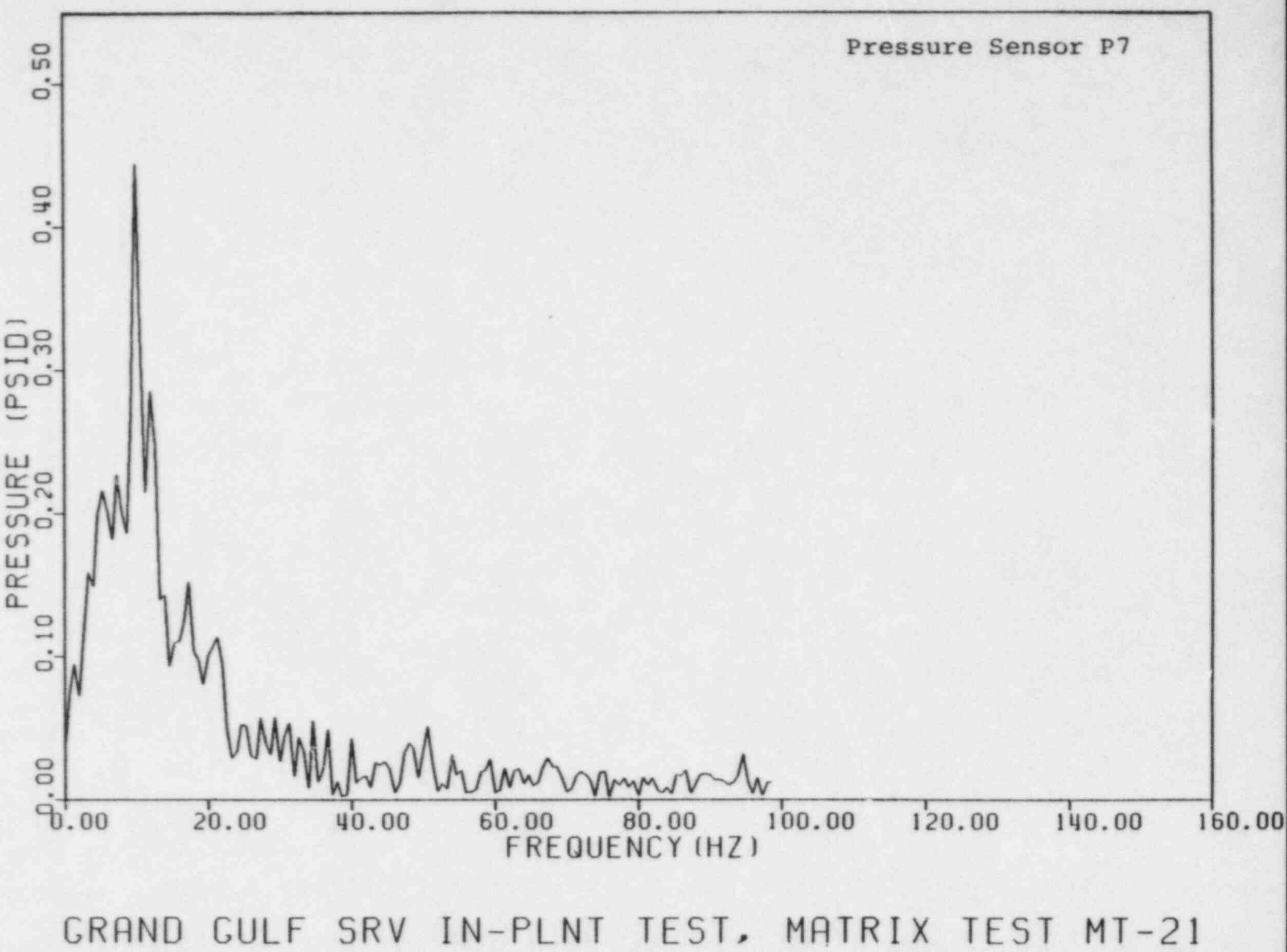


Figure 7.11

TYPICAL CVA PRESSURE PSD

nutech ENGINEERS

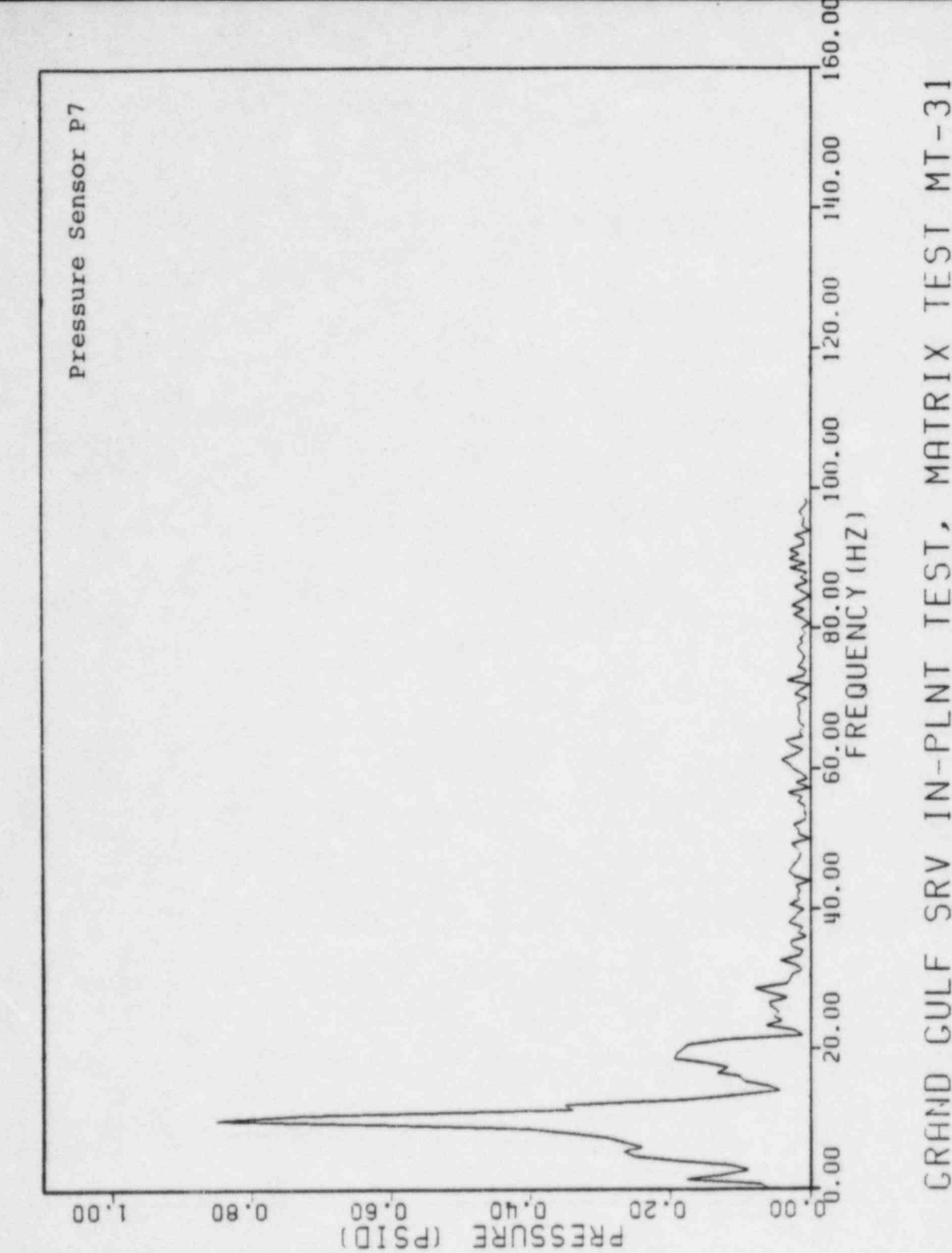


Figure 7.12

TYPICAL CVA PRESSURE PSD

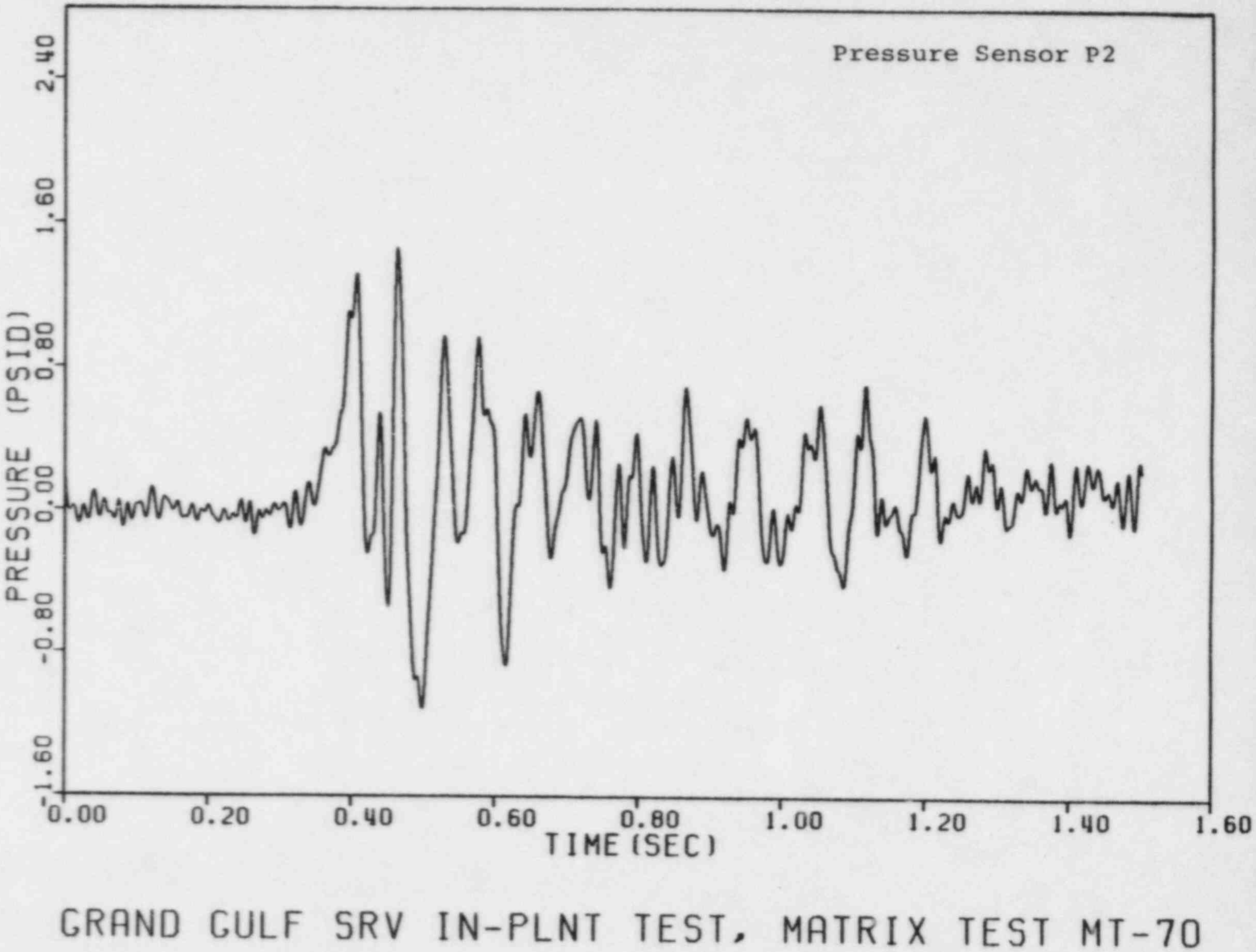
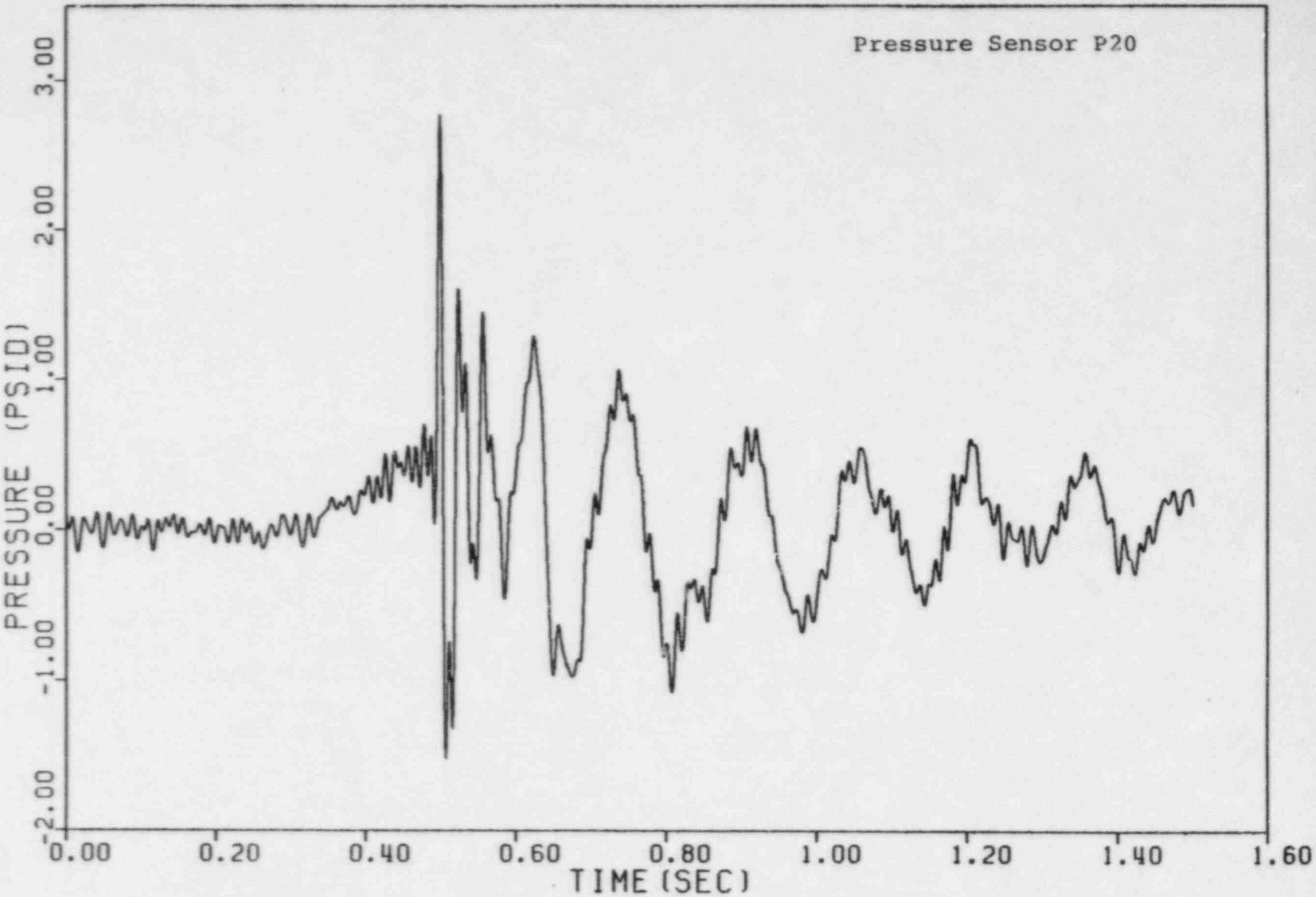


Figure 7.13

TYPICAL MVA PRESSURE TIME HISTORY



GRAND GULF SRV IN-PLNT TEST, MATRIX TEST MT-70

Figure 7.14

TYPICAL MVA PRESSURE TIME HISTORY

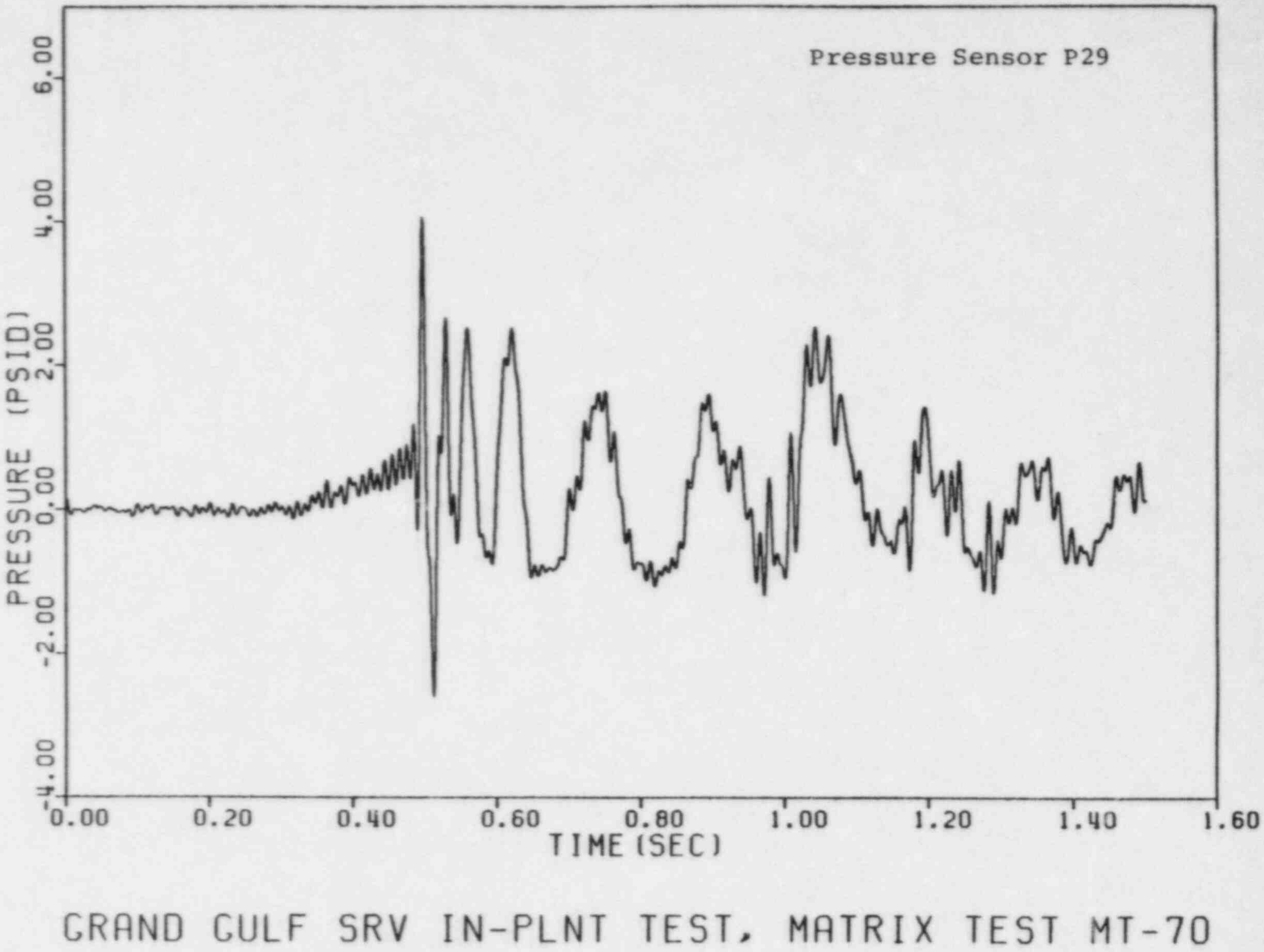


Figure 7.15

TYPICAL MVA PRESSURE TIME HISTORY

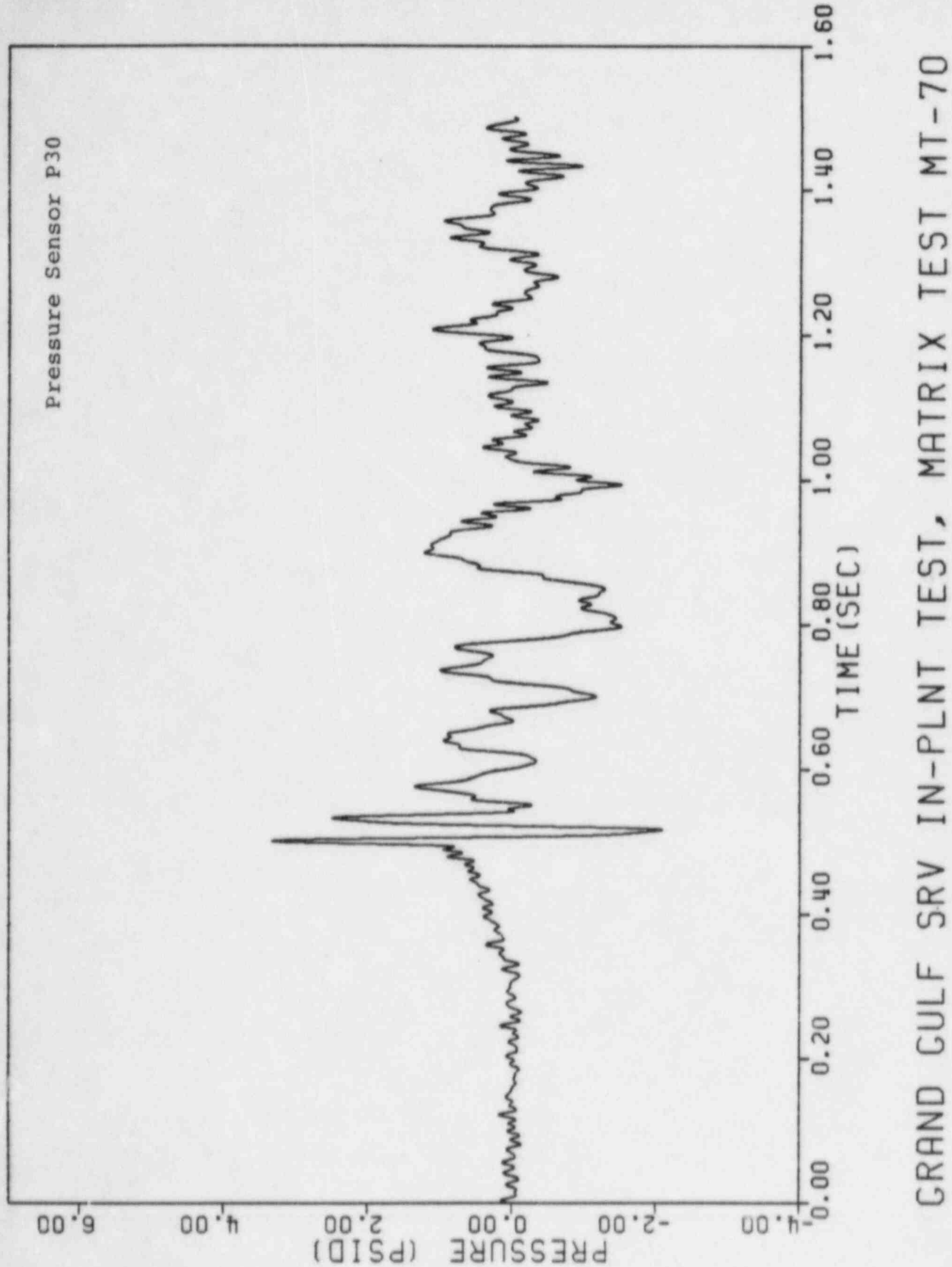


Figure 7.16

TYPICAL MVA PRESSURE TIME HISTORY

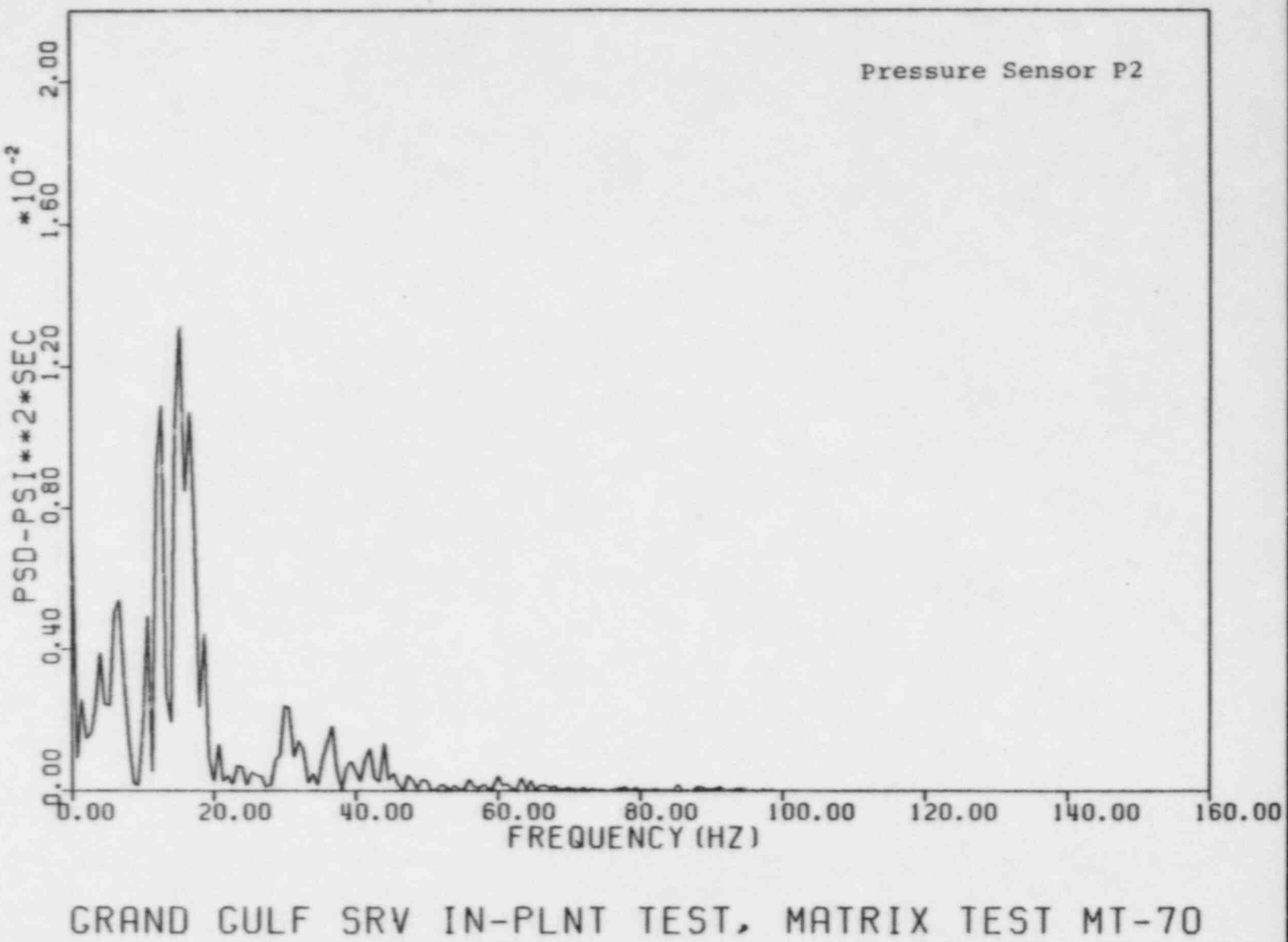
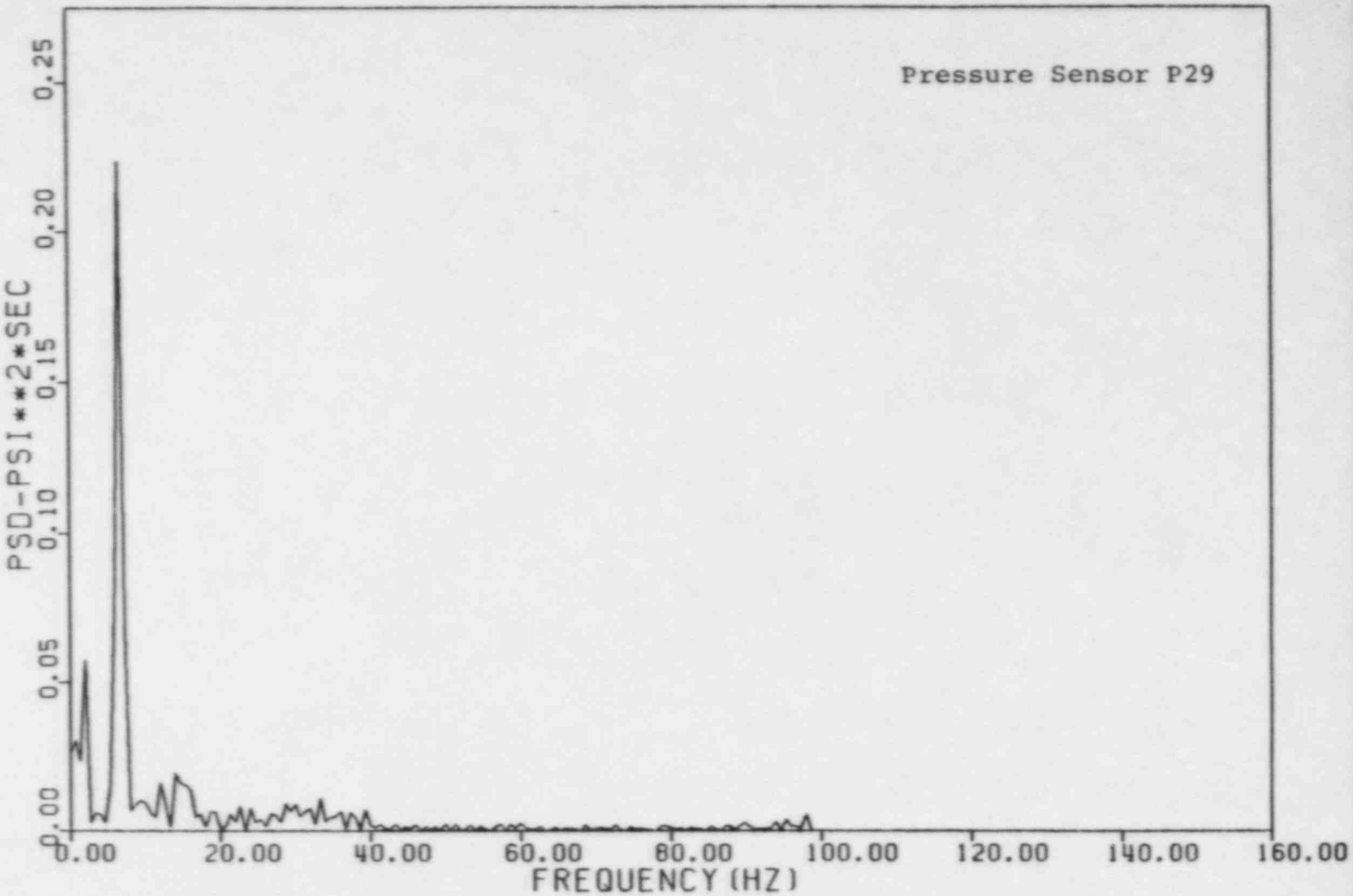


Figure 7.17
TYPICAL MVA PRESSURE PSD



GRAND GULF SRV IN-PLNT TEST, MATRIX TEST MT-70

Figure 7.18

TYPICAL MVA PRESSURE PSD

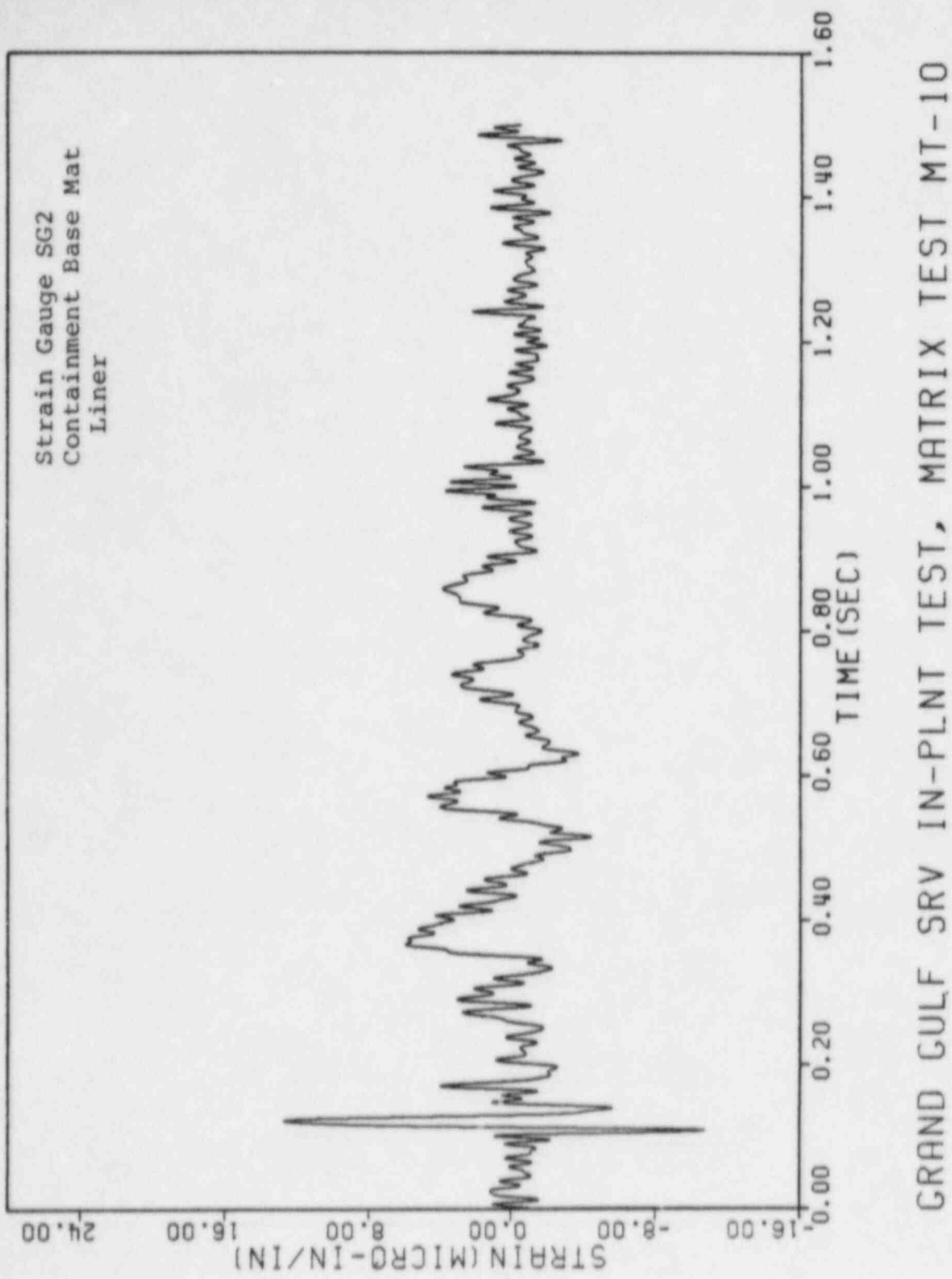


Figure 7.19

TYPICAL SVA STRAIN TIME HISTORY

MPL-01-220
Revision 0

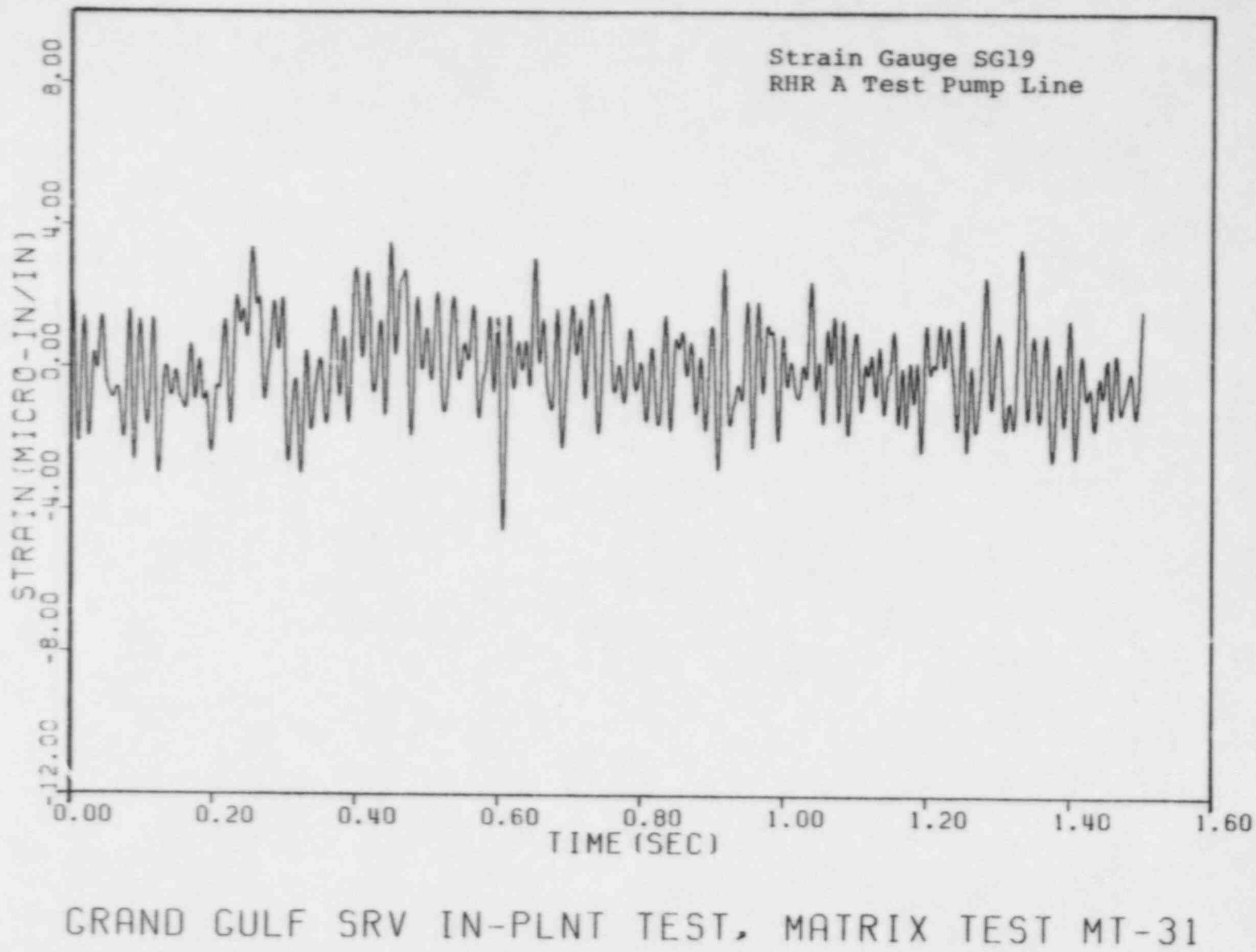
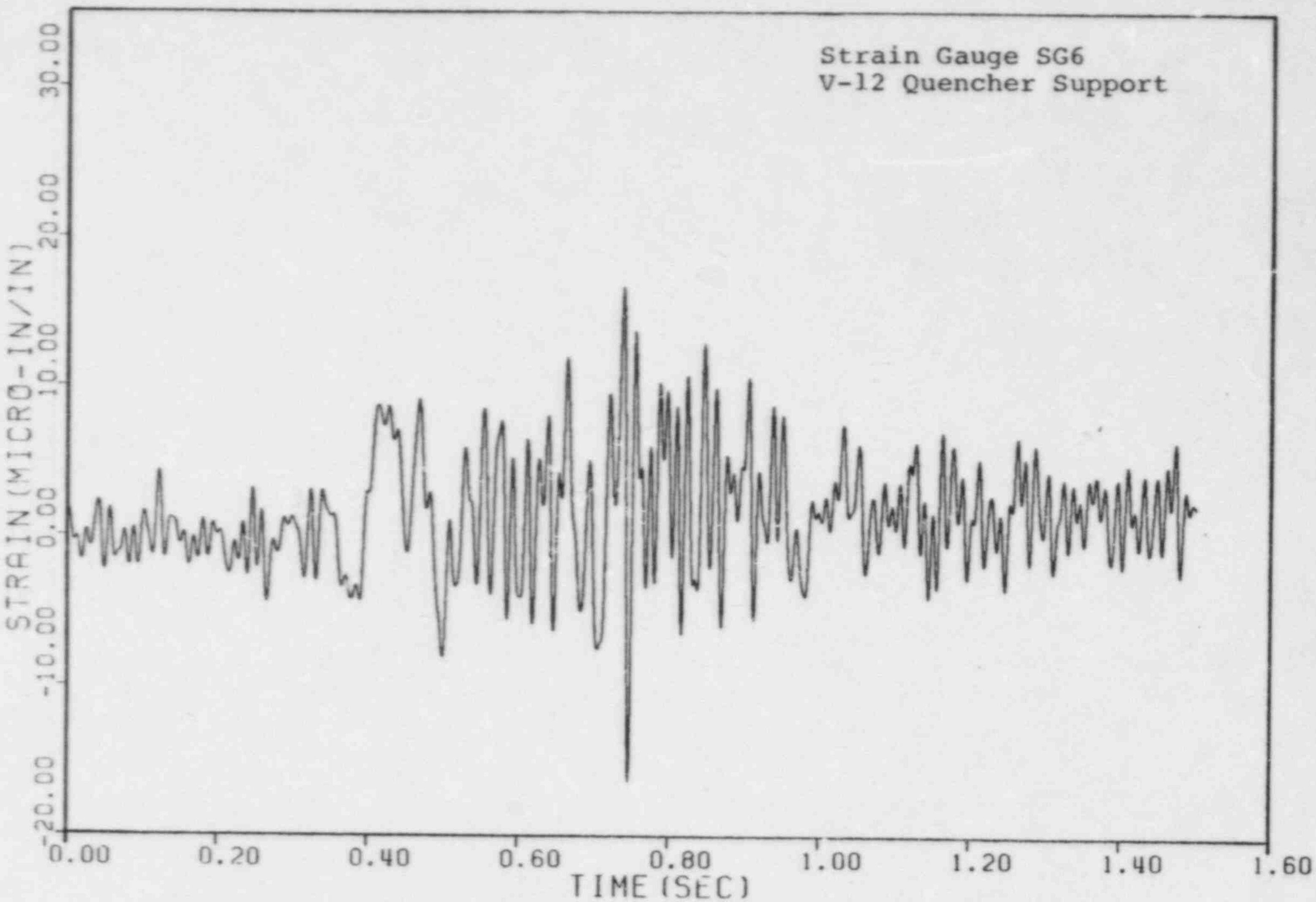


Figure 7.20

TYPICAL CVA STRAIN TIME HISTORY



GRAND CULF SRV IN-PLNT TEST, MATRIX TEST MT-70

Figure 7.21

TYPICAL MVA STRAIN TIME HISTORY

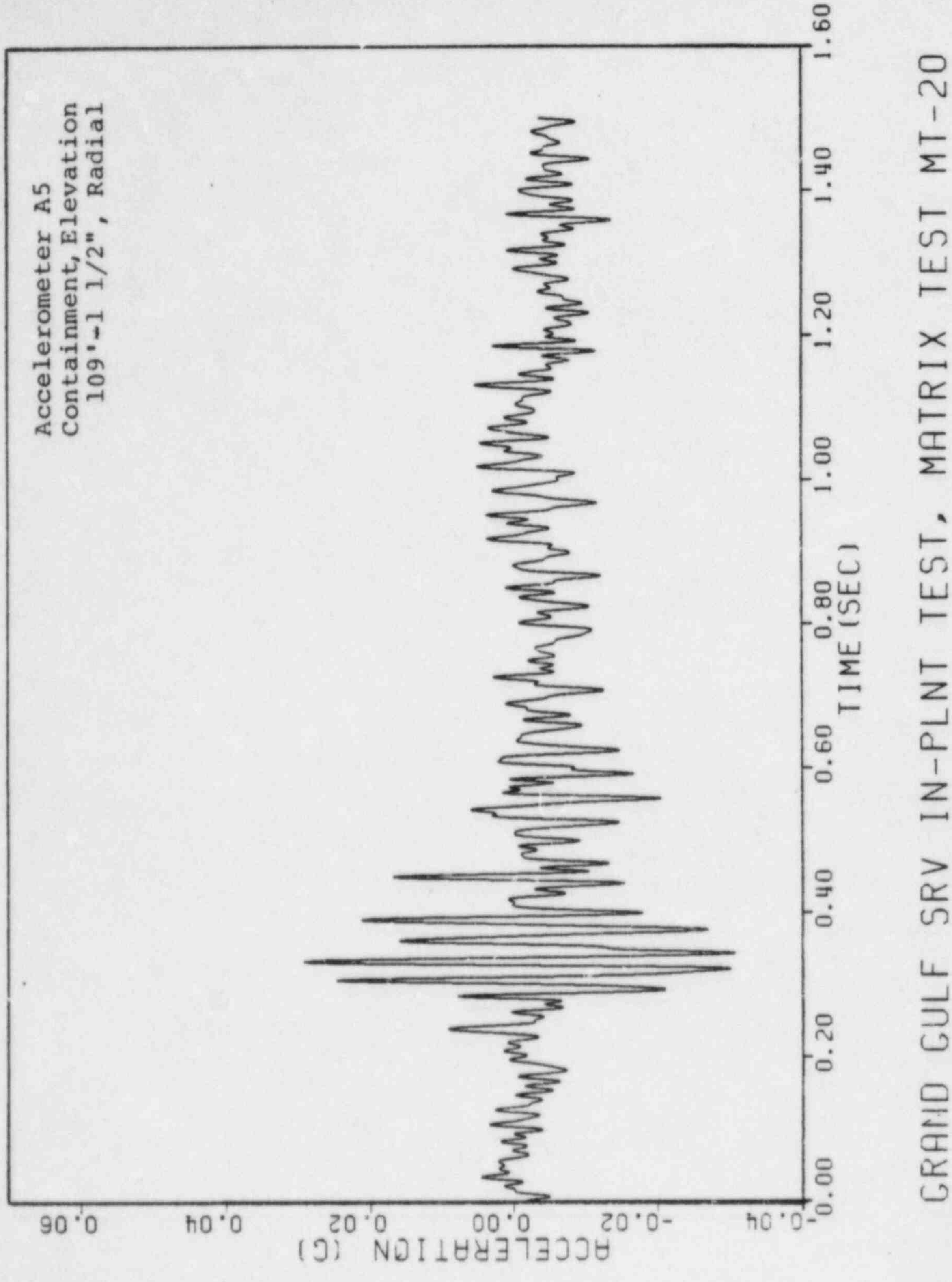


Figure 7.22

TYPICAL SVA ACCELERATION TIME HISTORY

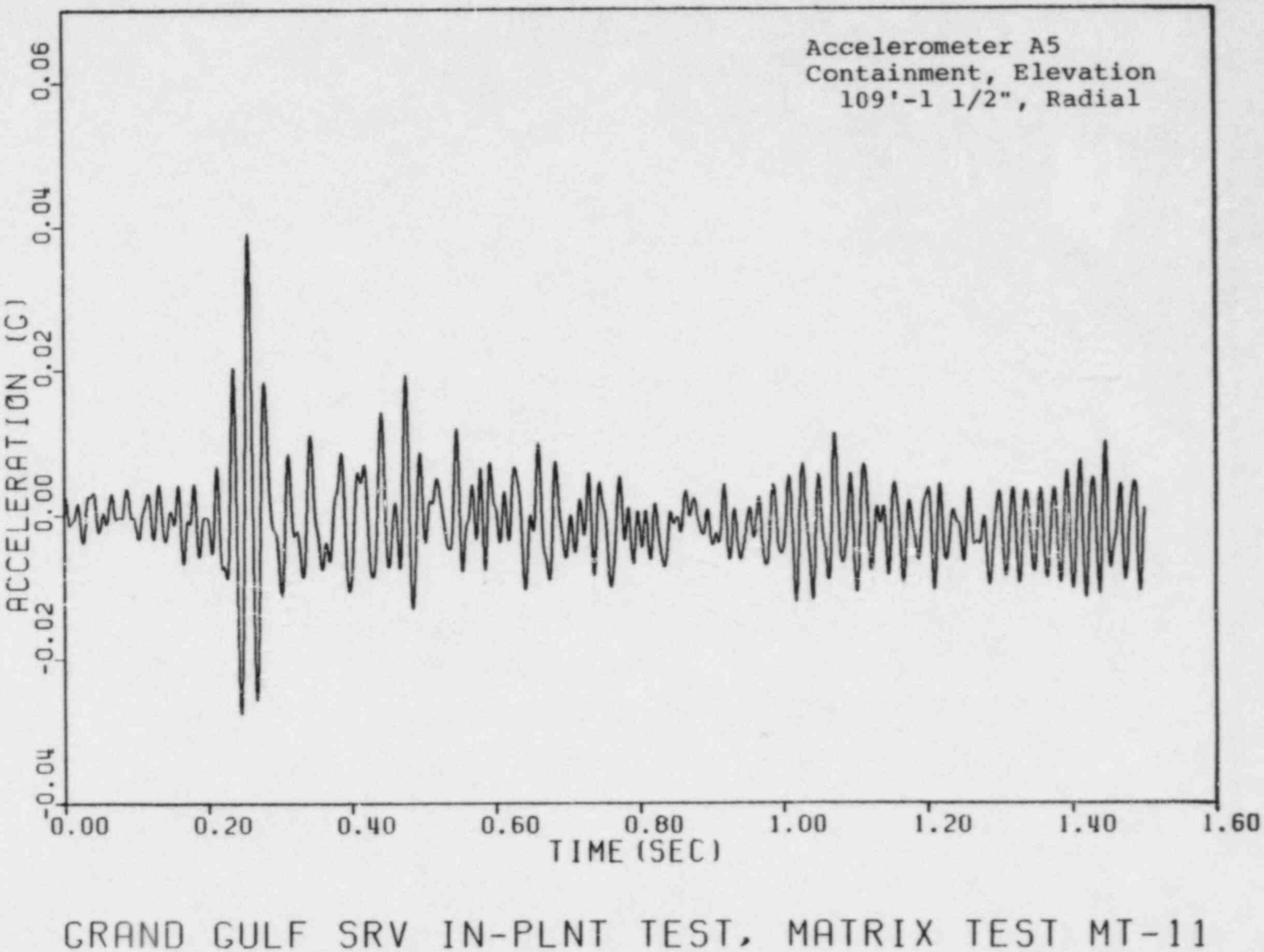


Figure 7.23
TYPICAL CVA ACCELERATION TIME HISTORY

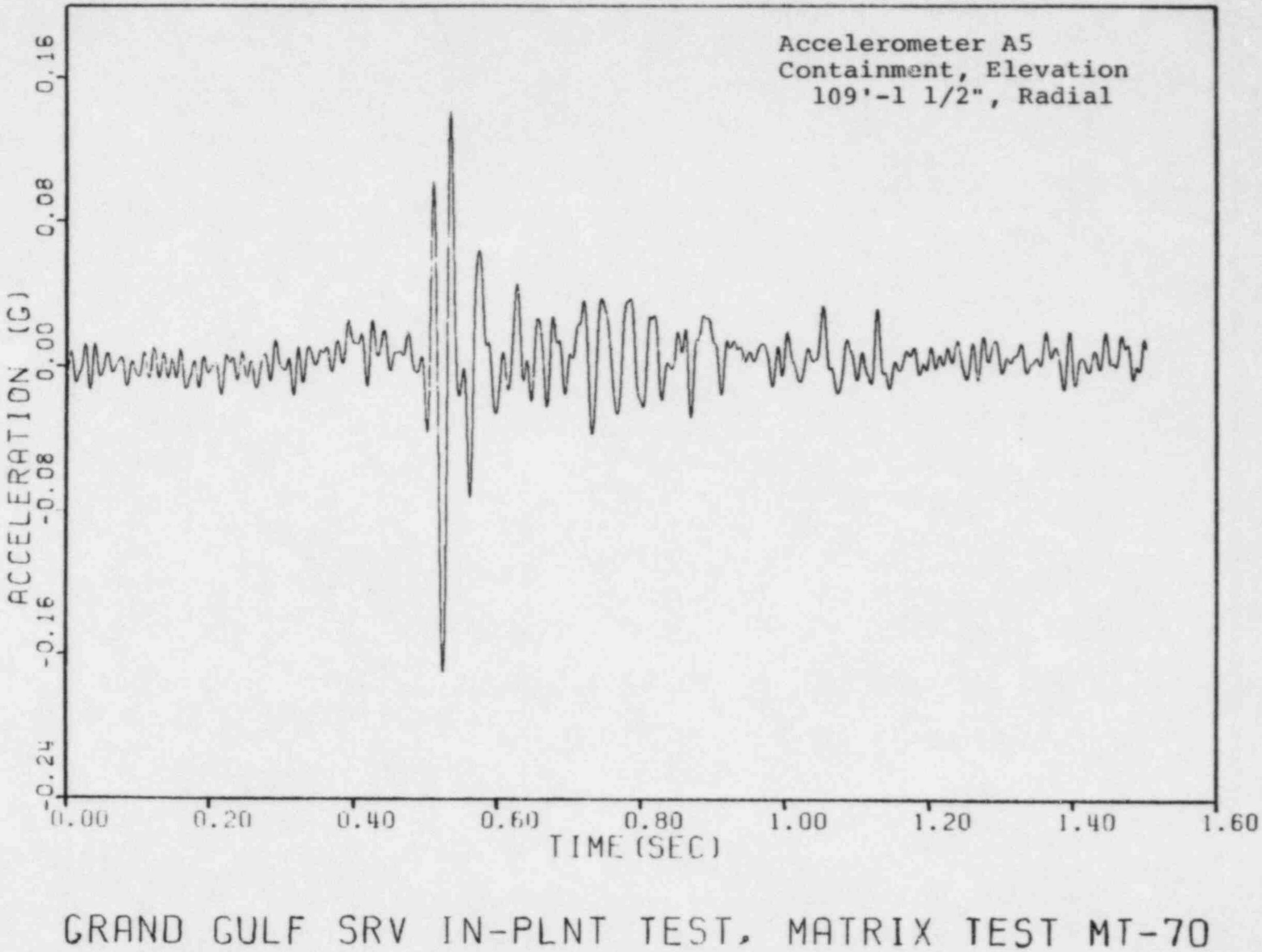


Figure 7.24

TYPICAL MVA ACCELERATION TIME HISTORY

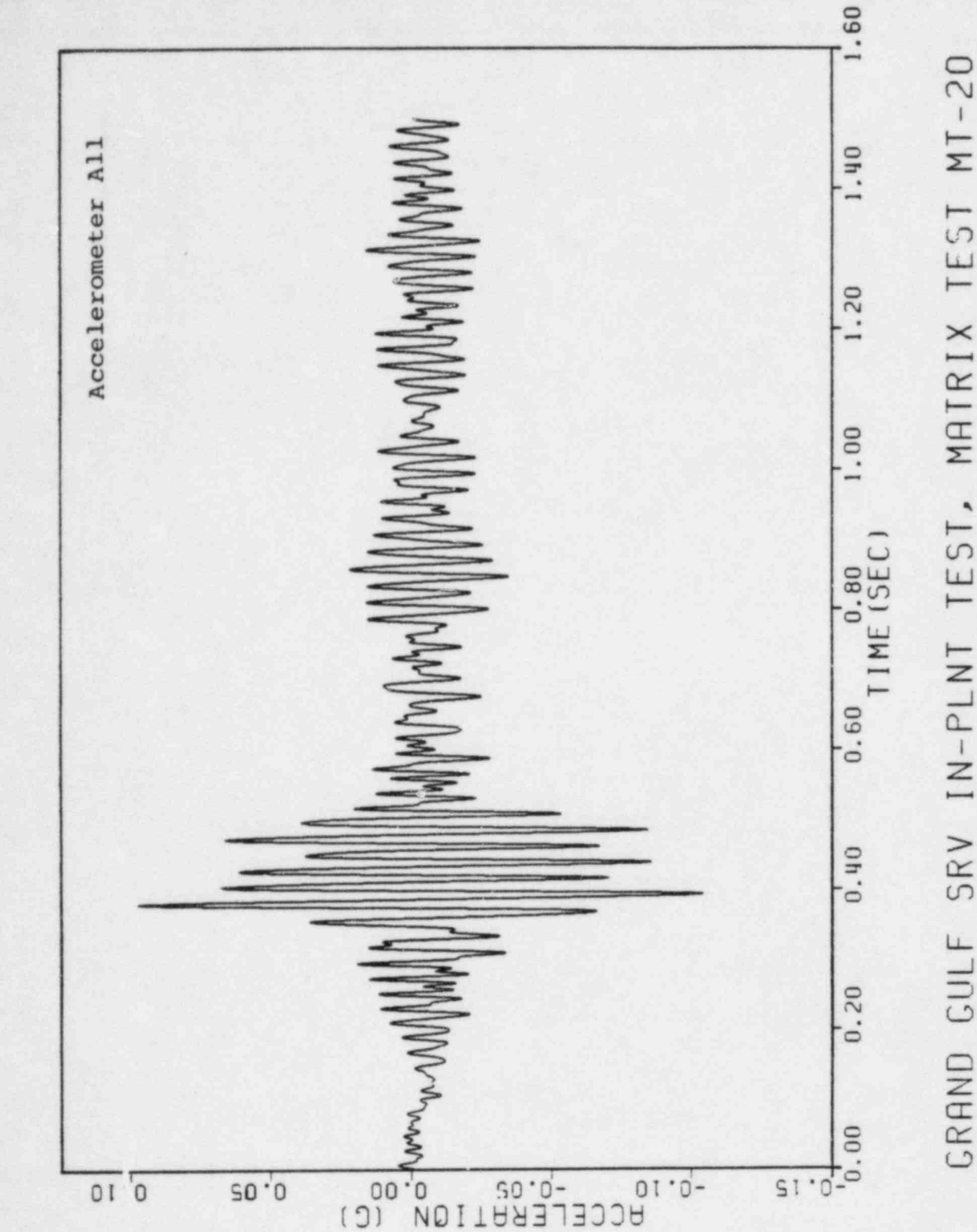


Figure 7.25

ACCELERATION TIME HISTORY FOR POLAR CRANE GIRDER

8.0 ACCELERATION RESPONSE SPECTRA

The acceleration response spectra, Figures 8.1 through 8.23, present the calculated response for structure mounted accelerometers for all seven tests plotted as three envelopes, one each for SVA, CVA and MVA results. The Grand Gulf design spectra for the single valve (SRV_{one}) and all valve (SRV_{all}) cases are also plotted on Figures 8.1 through 8.23. This provides a comparison of measured test results to design values. The comparison of design versus measured response spectra, given in Figures 8.1 through 8.23, shows that there is little of the low frequency (less than 60 Hz) response predicted by the analysis. Four of the test spectra (A1, A8, A15, and A16) slightly exceed the design spectra at frequencies above 60 Hz. And three test spectra (A13, A21, and A22) show small exceedences of the design spectra above 40 Hz. However, as noted in Section 7.4, this has no influence on the containment attached piping or Reactor Building equipment. This is clearly shown in the minimal measured response of containment mounted piping and equipment.

In addition, Reference 16, showed that these anticipated high frequency exceedances were not a concern for the Grand Gulf piping or equipment. The principal conclusions of Reference 16 can be summarized as:

- Grand Gulf measured structural accelerations (zero period accelerations) were less than the predicted values for all tests as shown in Table 7.6. The high frequency test response spectra exceedances are of little concern to piping design or equipment and component qualification.

- Modal participation factors, and the percent relative contribution of each mode, for five Grand Gulf critical piping systems were studied. The studies showed that between 50% to 90% of the total system response is captured by modes with frequencies less than 30 Hz, and less than 10% of the total system response comes from frequencies above 60 Hz. Therefore, as much as an order of magnitude less piping system response would be expected if the test spectra were used instead of design spectra for the SRV discharge load contribution to the total stresses.

- All equipment and components in the Grand Gulf reactor building have been requalified by analysis and/or test for SSE + SRV + LOCA DBA loads. This qualification level is multifrequency and is generally considerably higher than the measured test spectra. Thus, the relatively low amplitude, high frequency test spectra exceedances do not have any impact on the equipment or component qualifications.

Acceleration response spectra are not reported for the following locations:

- A2, containment vessel basemat. Measured accelerations are incorrect as noted in Section 7.4.

- A11 and A12, polar crane girder. Measured local response of girder not that of the containment shell, design spectra are not available.

- A23 and A24, top of fuel pool wall elevation 208'-10". Design spectra not available for comparison. Magnitudes and frequency content similar to A21 and A22.

- A29 to A52, equipment mounted accelerometers. These pieces of equipment are qualified and designed for peak accelerations. As shown by Table 7.6 the design values are very conservative when compared with test results.

- A53 to A56, Auxiliary building. Design spectra were not developed for carry over of SRV response to the Auxiliary building. This assumption is shown to be correct by the very small magnitude of zpa reported in Table 7.6.

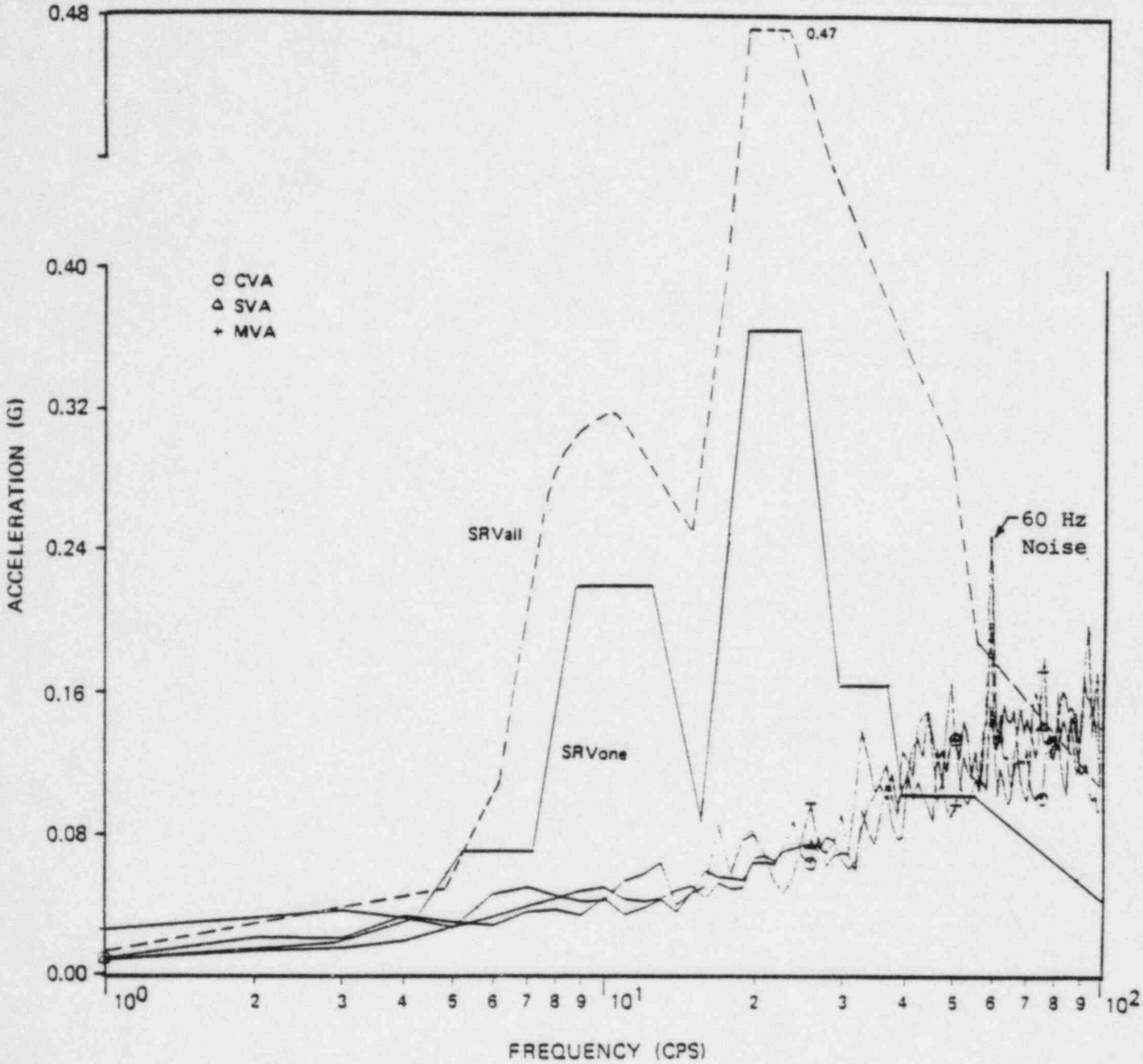


Figure 8.1

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A1
CONTAINMENT BASE MAT. ELEV. 93'-0", RADIAL

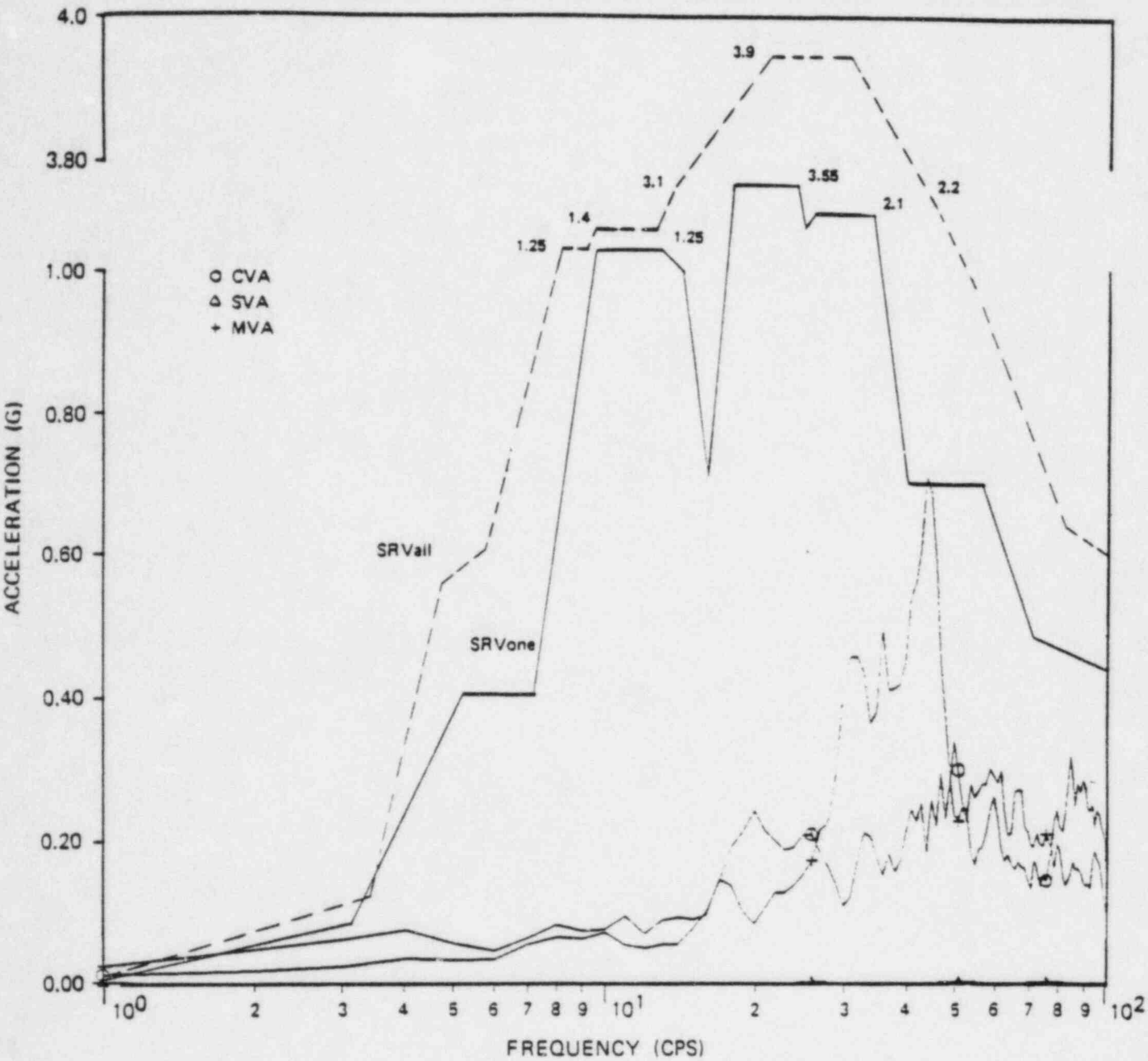


Figure 8.2

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A3
CONTAINMENT ELEV. 109'-1 1/2", RADIAL

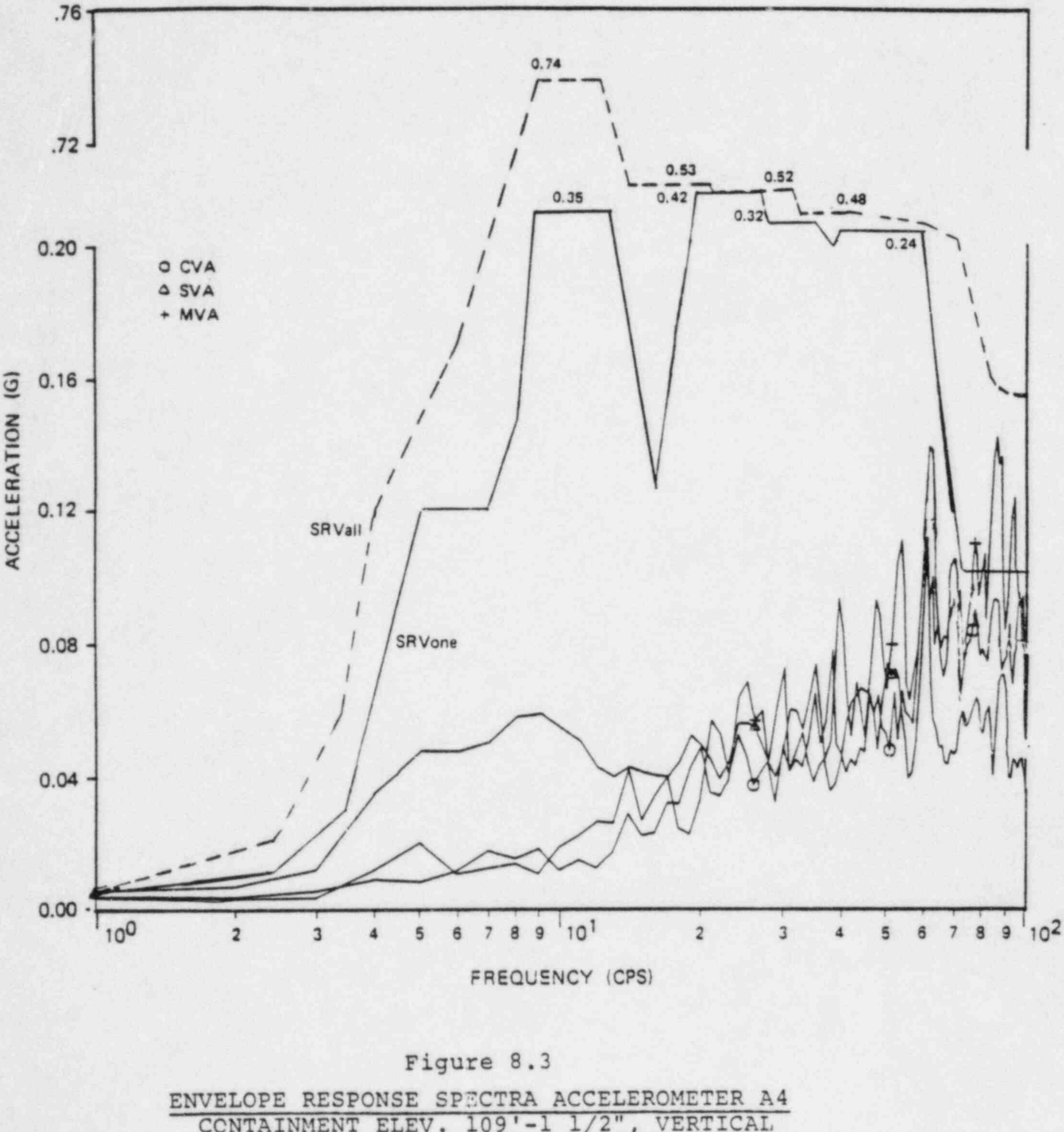


Figure 8.3

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A4
CONTAINMENT ELEV. 109'-1 1/2", VERTICAL

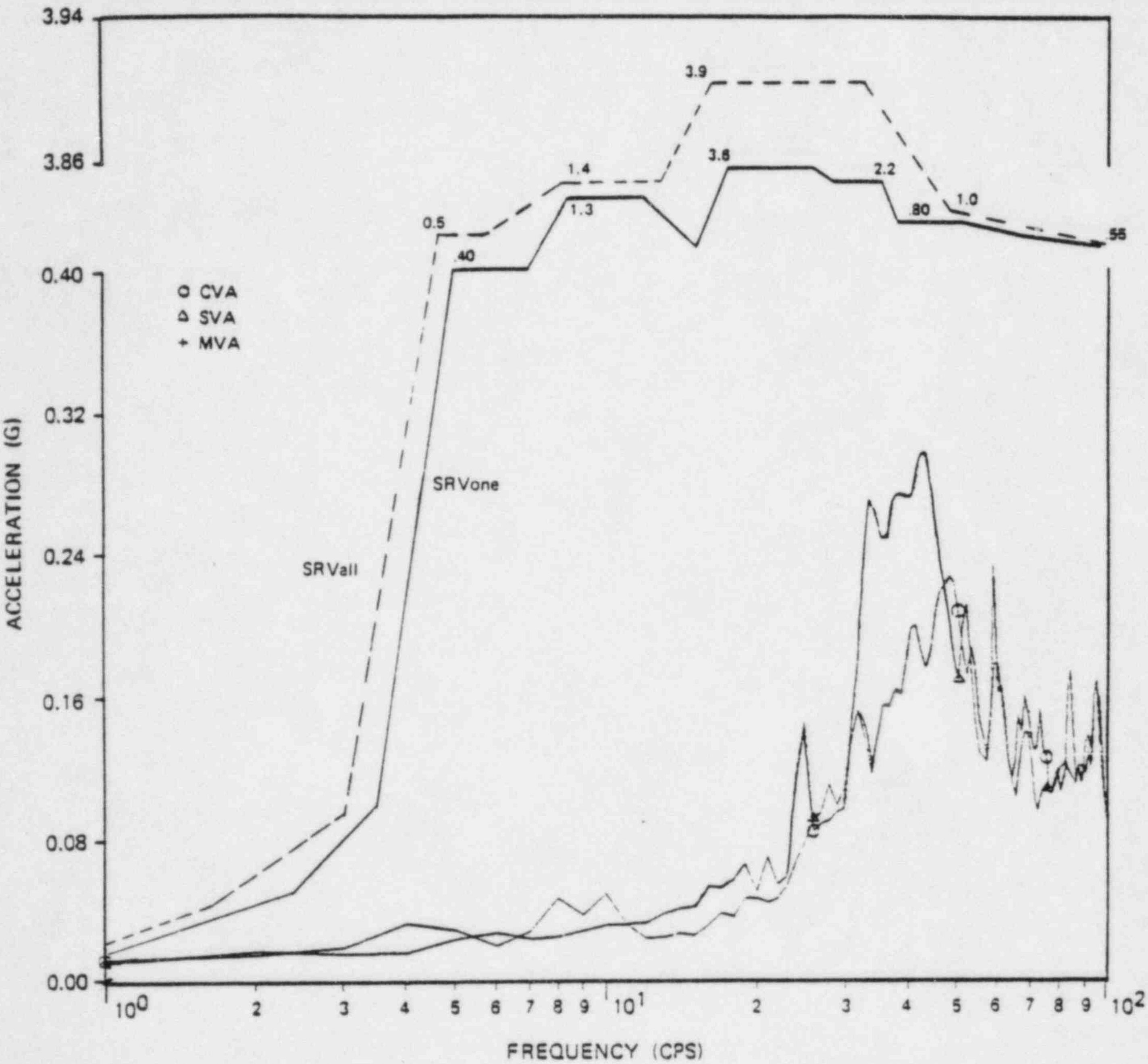


Figure 8.4

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A5
CONTAINMENT ELEV. 109'-1 1/2", RADIAL

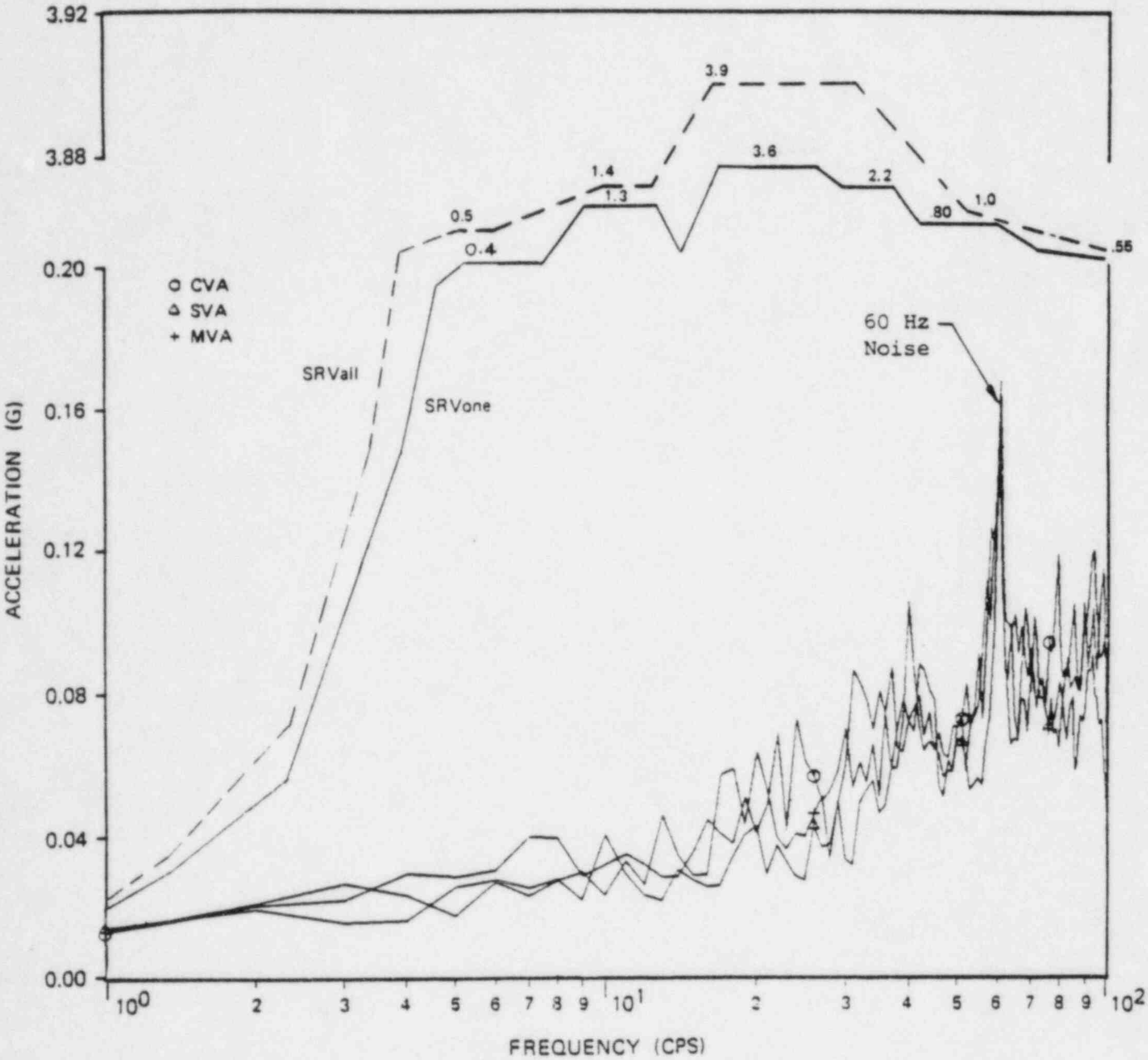


Figure 8.5

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A6
CONTAINMENT ELEV. 109'-1 1/2", TANGENTIAL

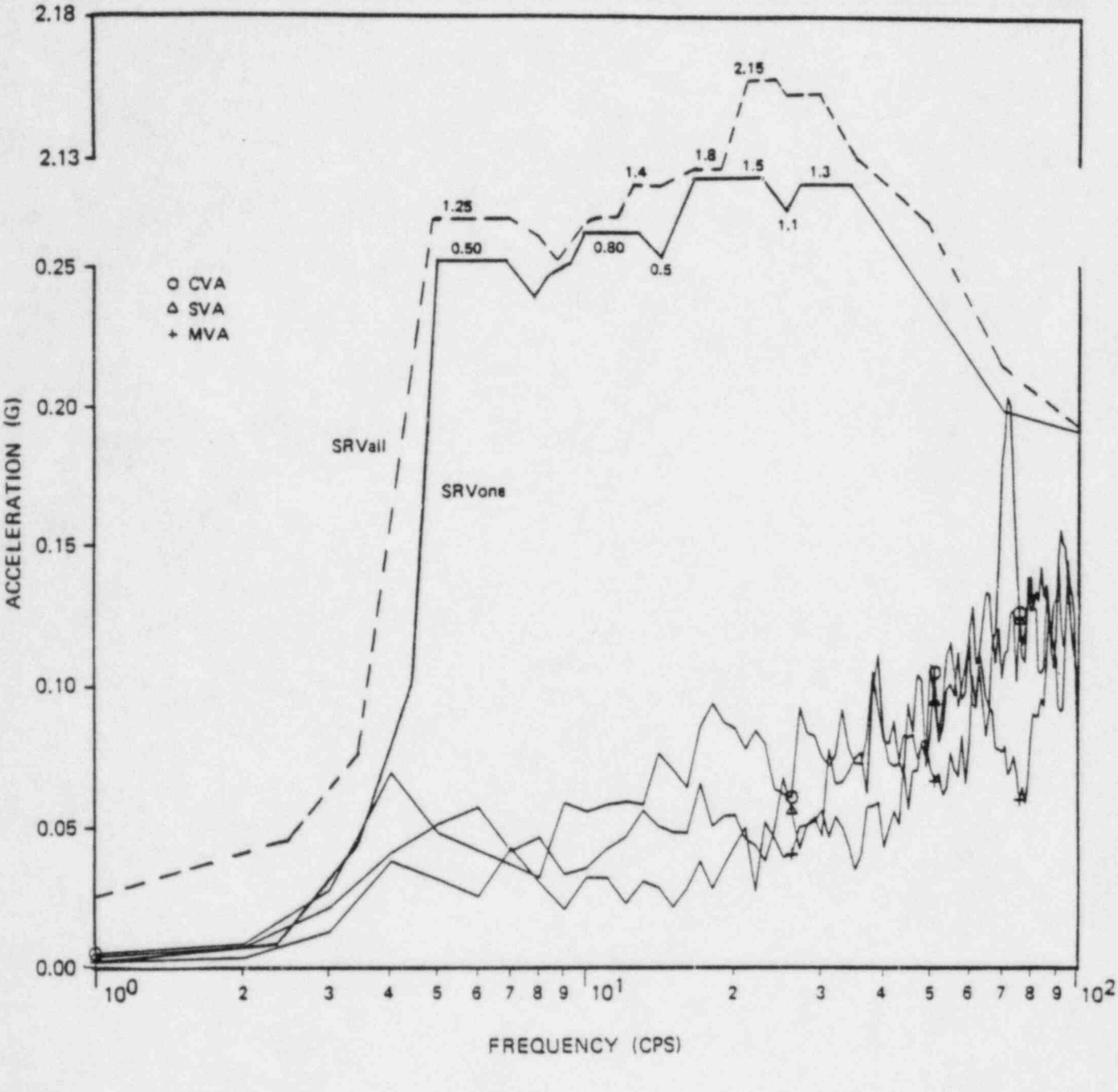


Figure 8.6

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A7
CONTAINMENT ELEV. 147'-7", RADIAL

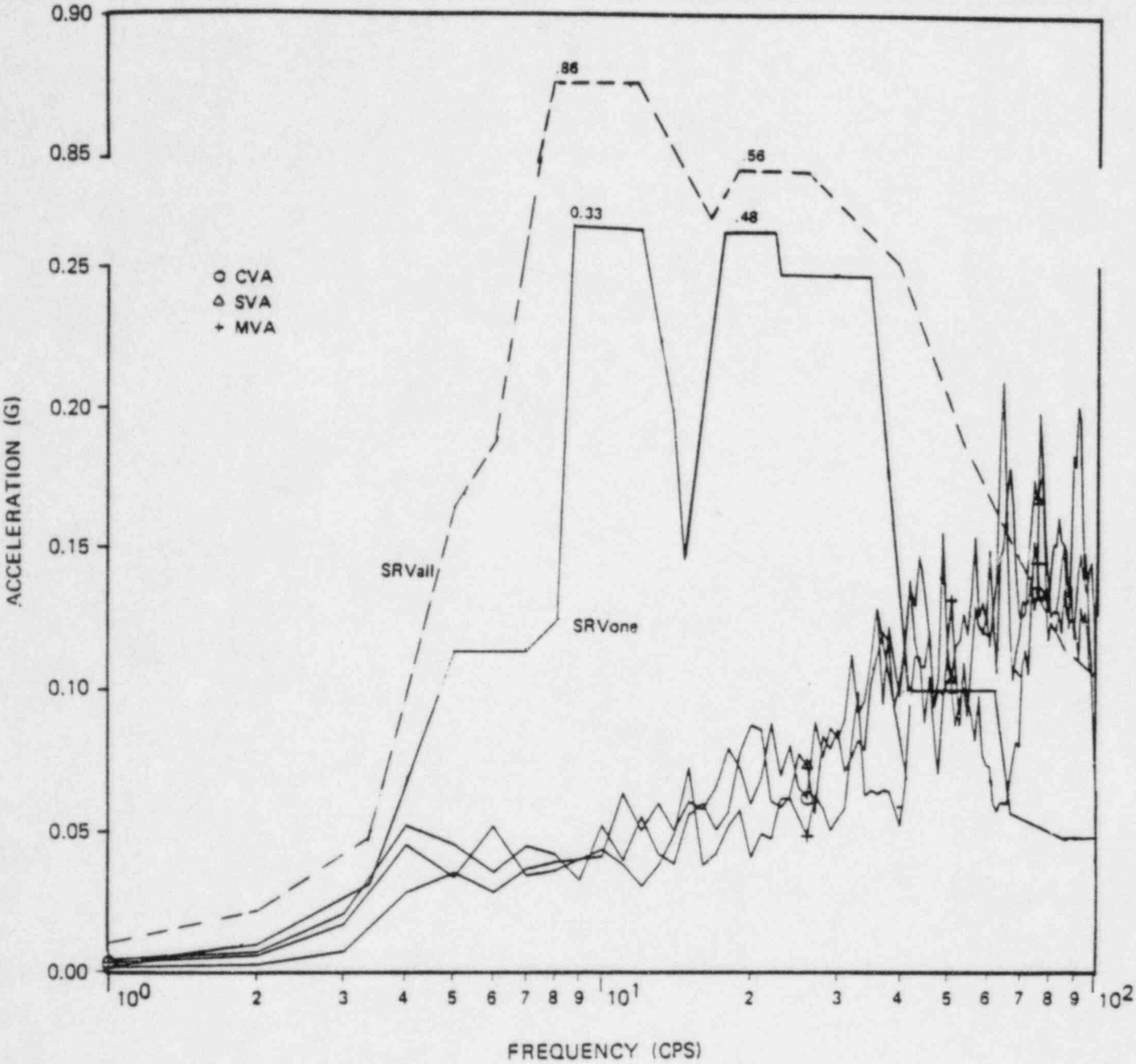


Figure 8.7

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A8
CONTAINMENT ELEV. 147'-7", VERTICAL

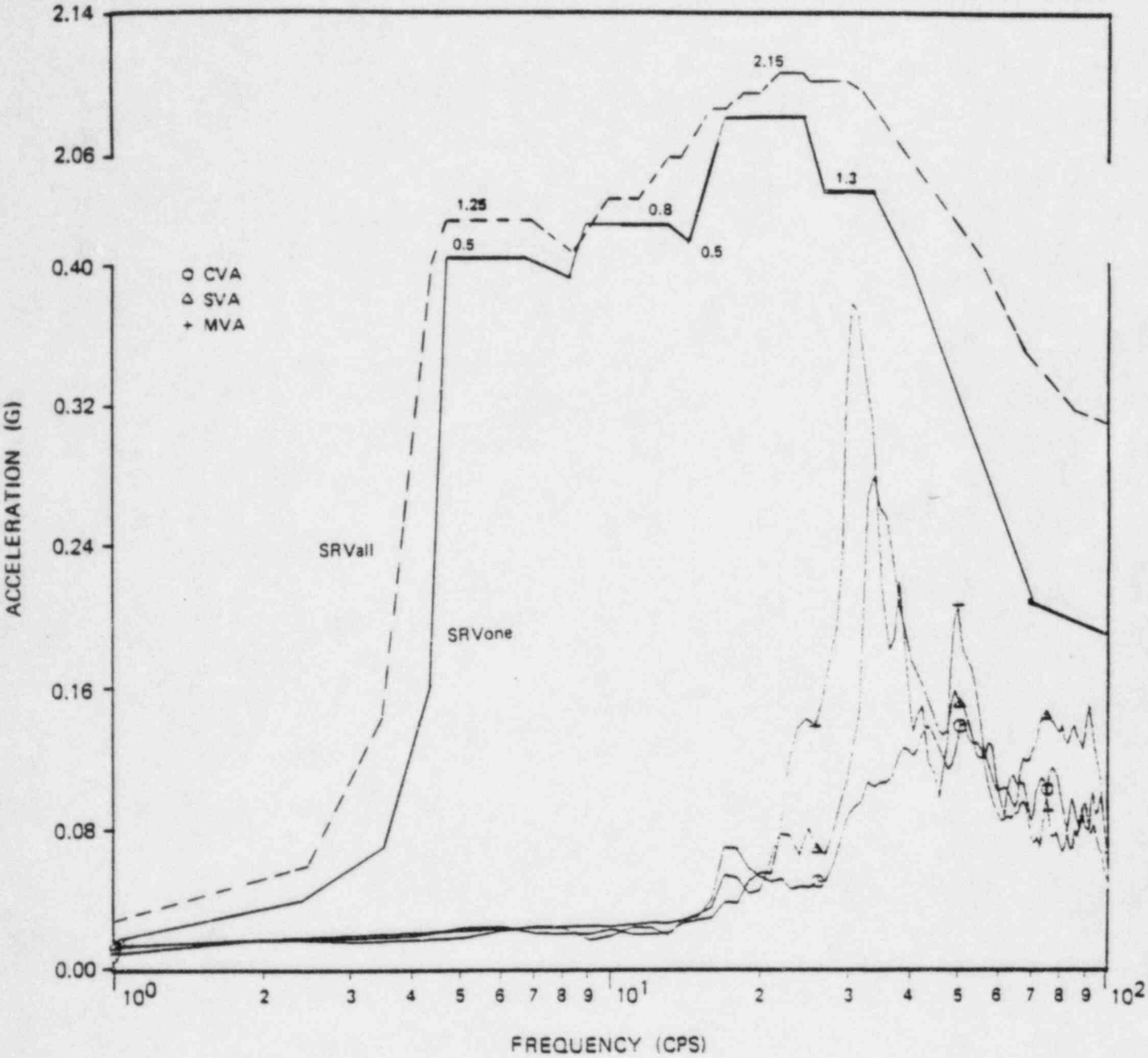


Figure 8.8

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A9
CONTAINMENT ELEV. 147'-7", RADIAL

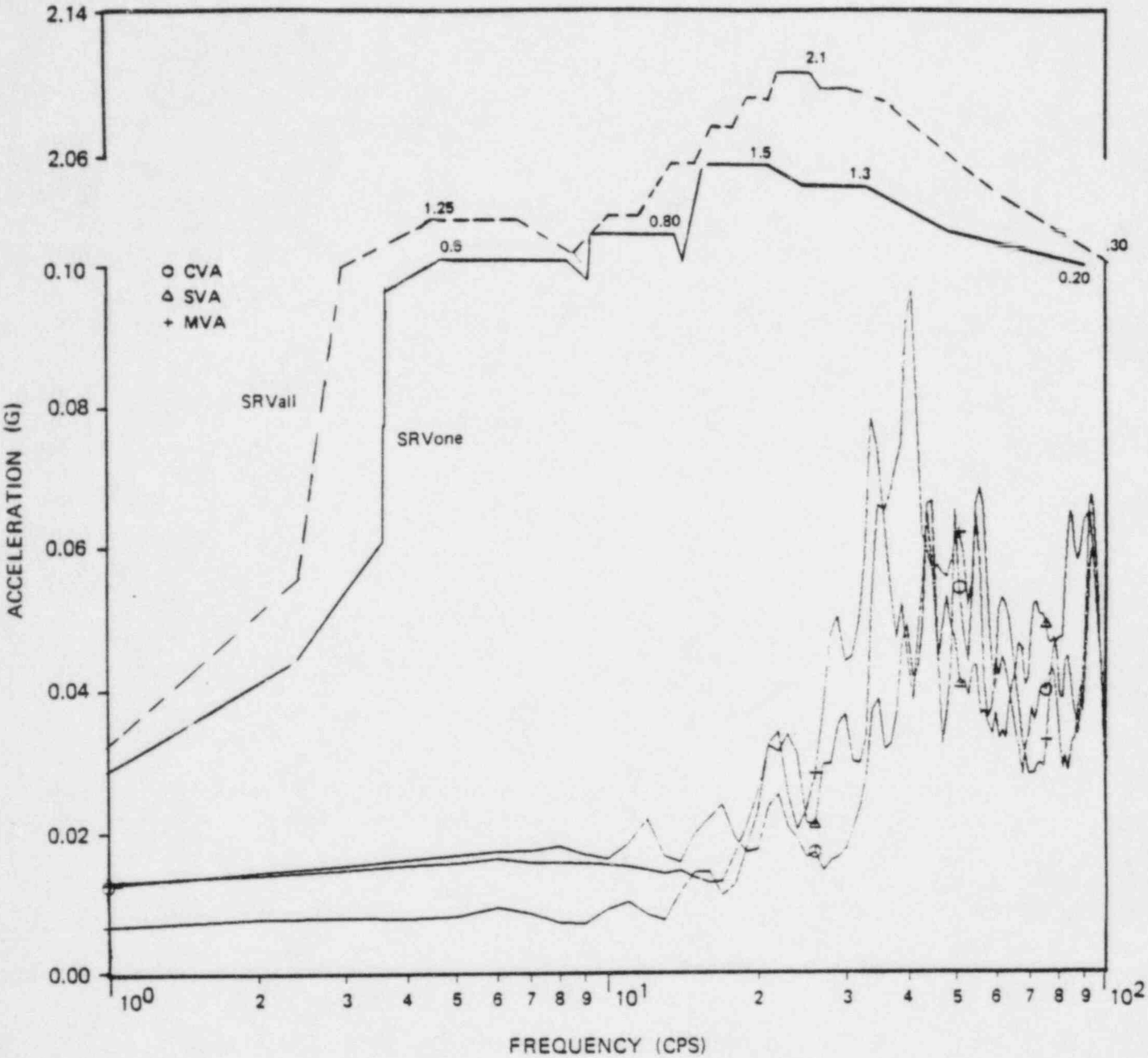


Figure 8.9

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A10
CONTAINMENT ELEV. 147'7", TANGENTIAL

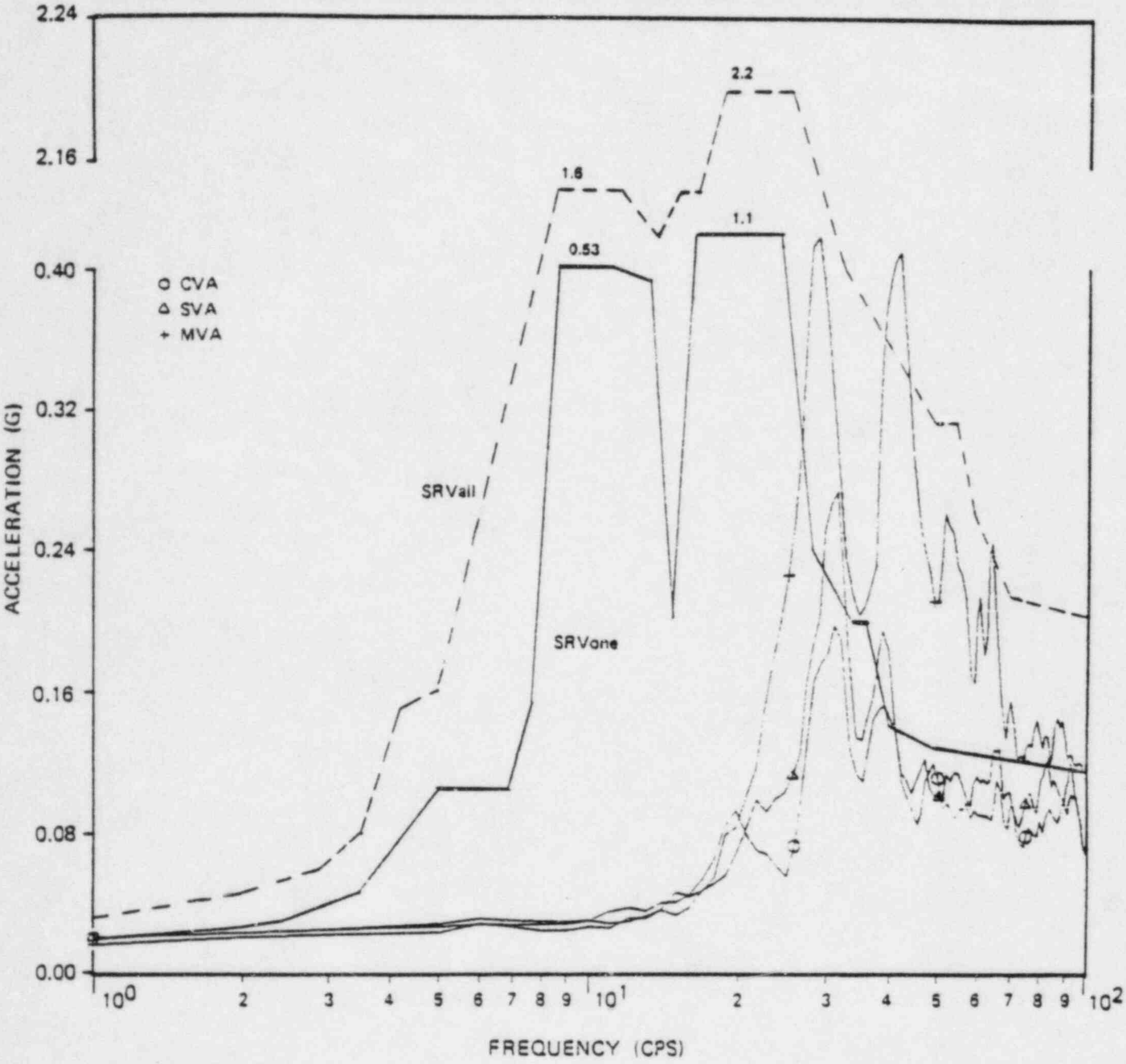


Figure 8.10

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A13
CONTAINMENT DOME ELEV. 302'-3", VERTICAL

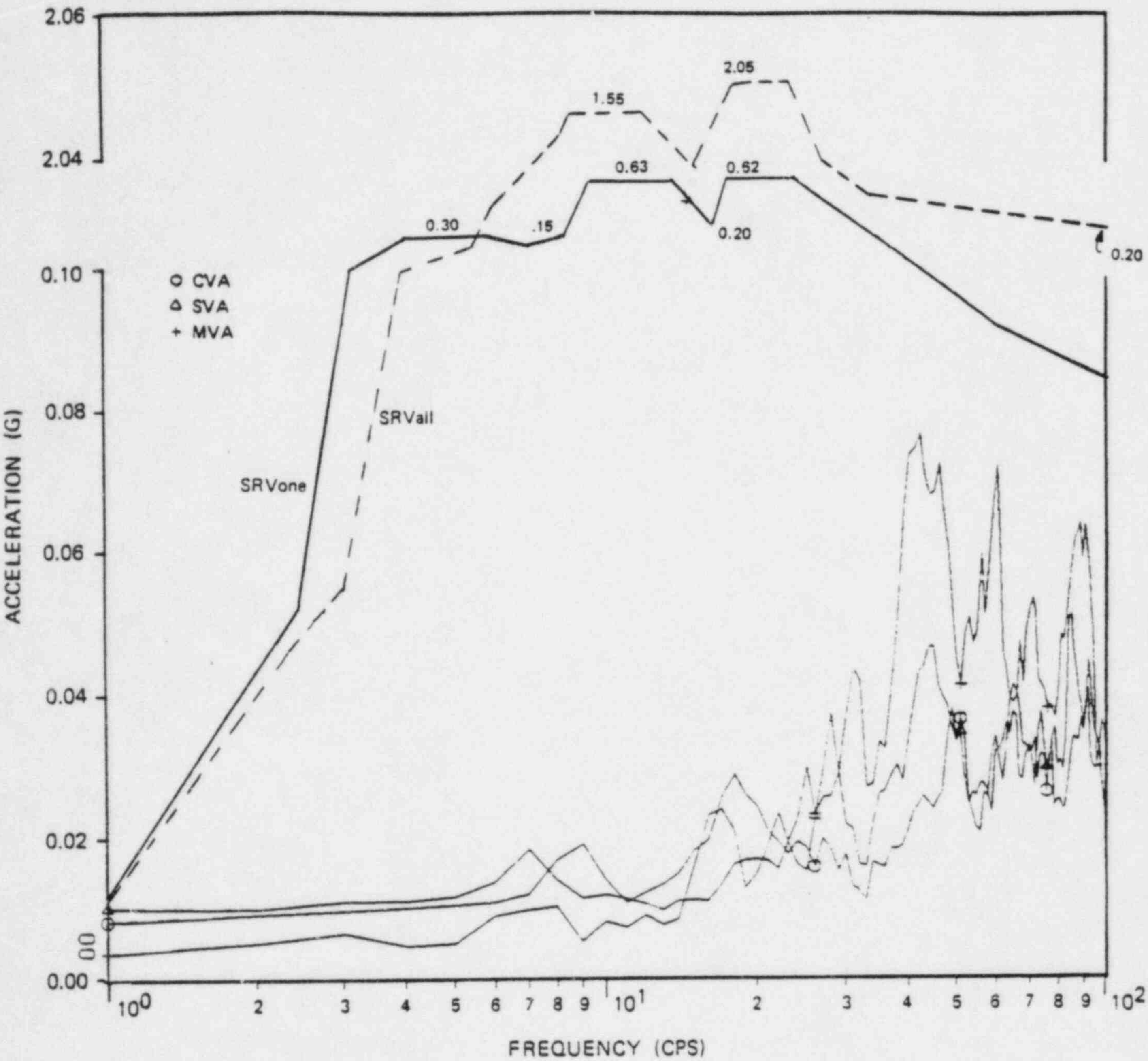


Figure 8.11

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A14
CONTAINMENT DOME ELEV. 302'-3", RADIAL

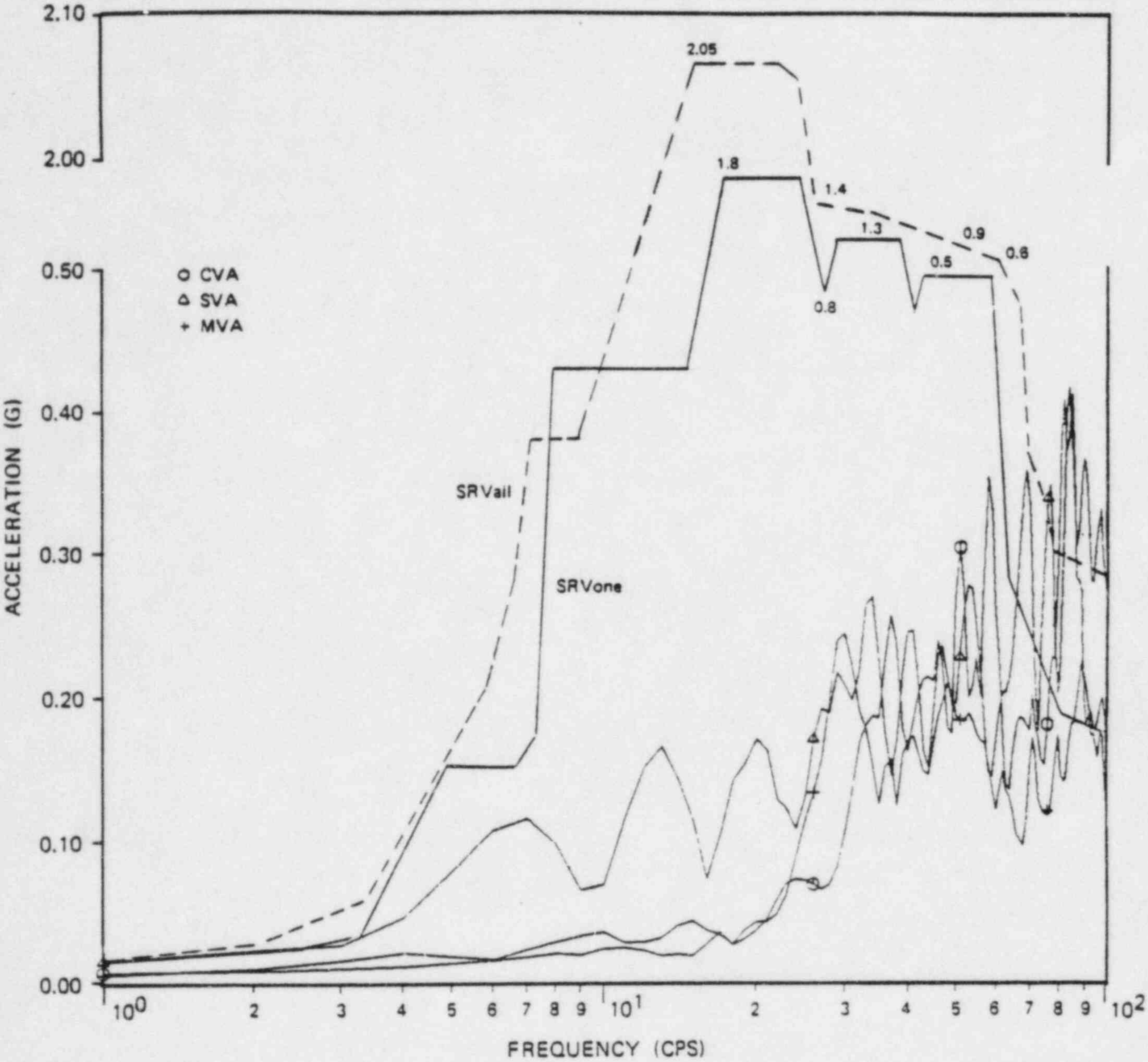


Figure 8.12

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A15
DRYWELL ELEV. 120'-10", RADIAL

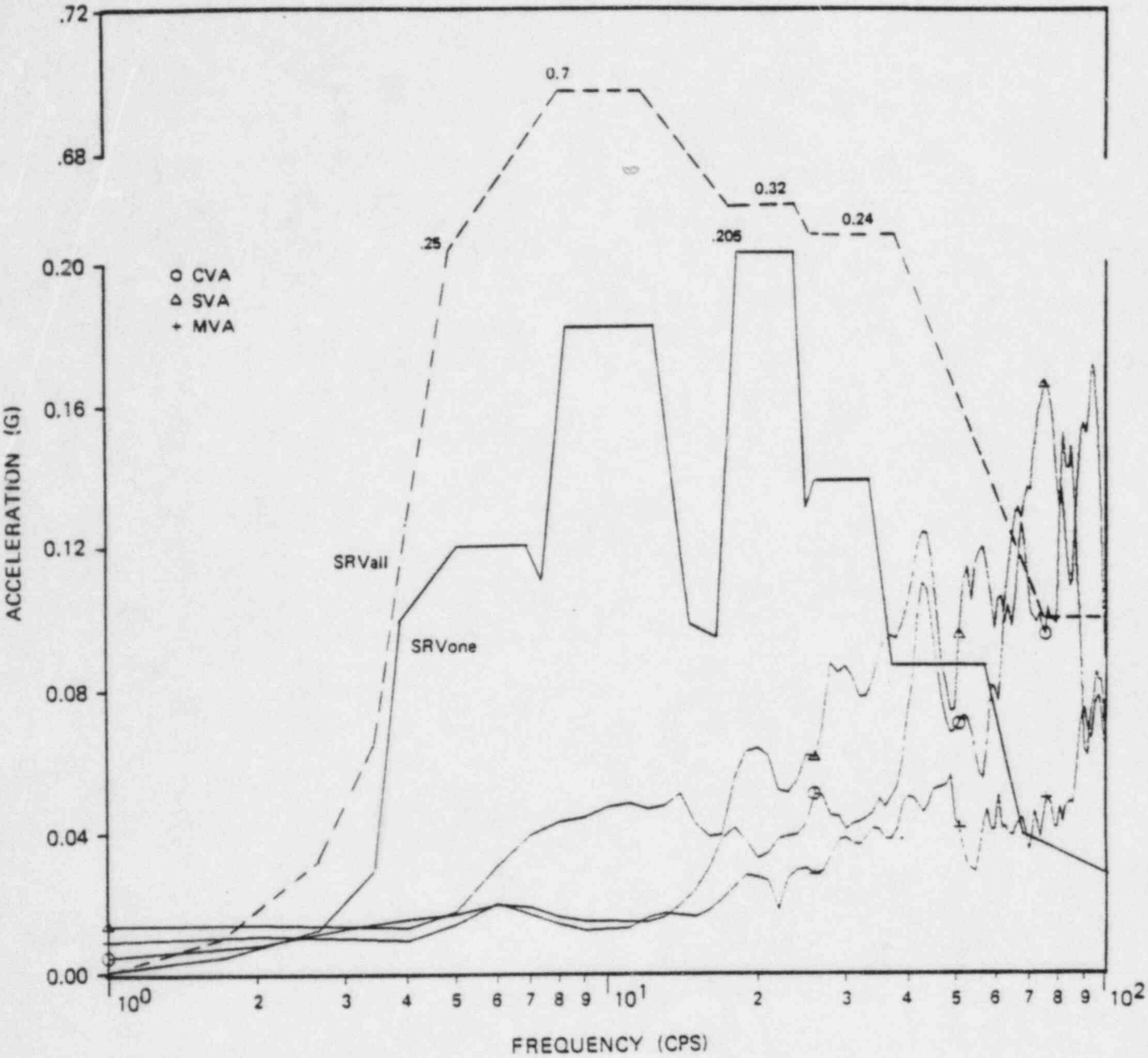


Figure 8.13

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A16
DRYWELL ELEV. 120'-10",VERTICAL

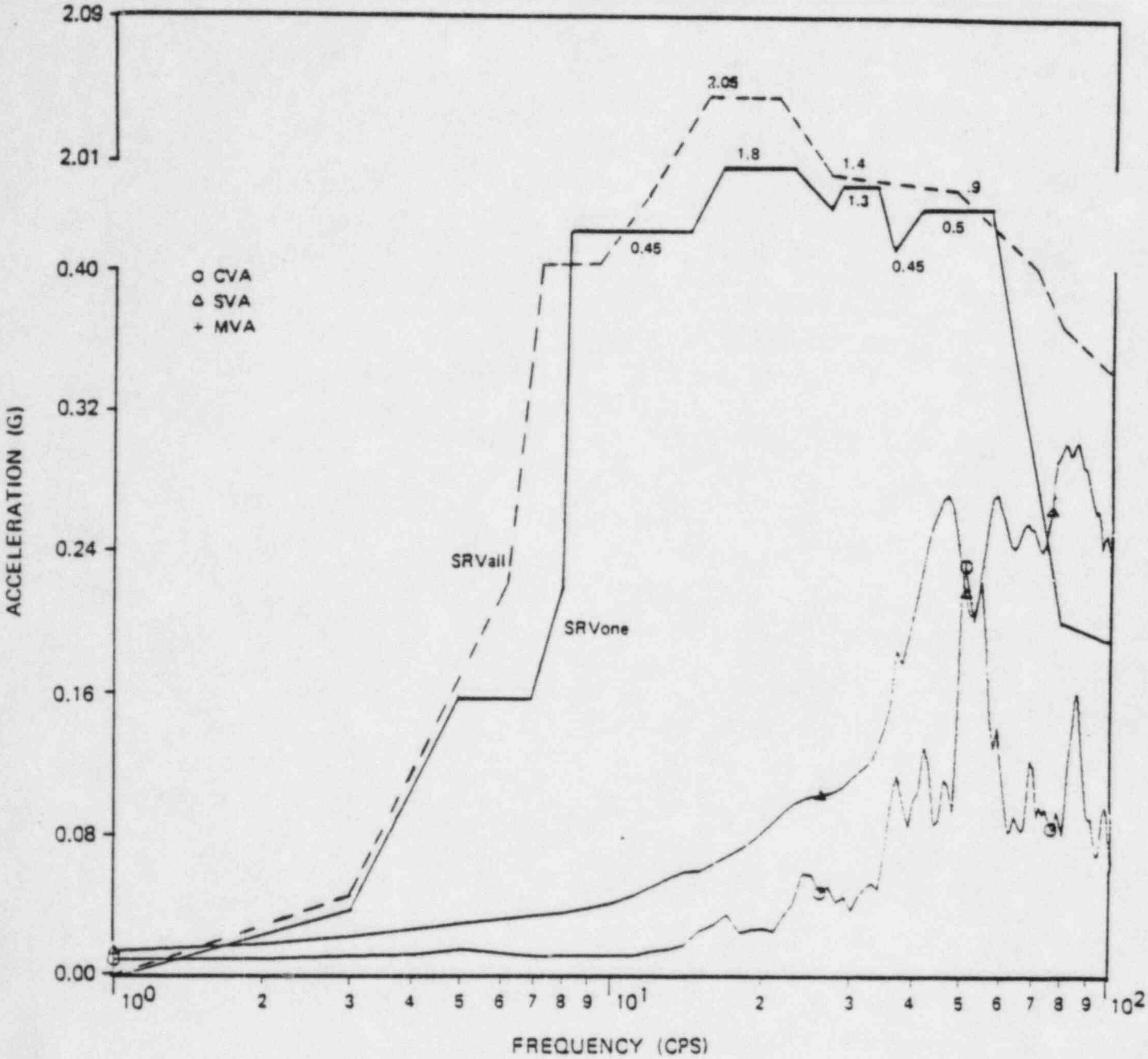


Figure 8.14

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A17
DRYWELL ELEV. 120'-10", RADIAL

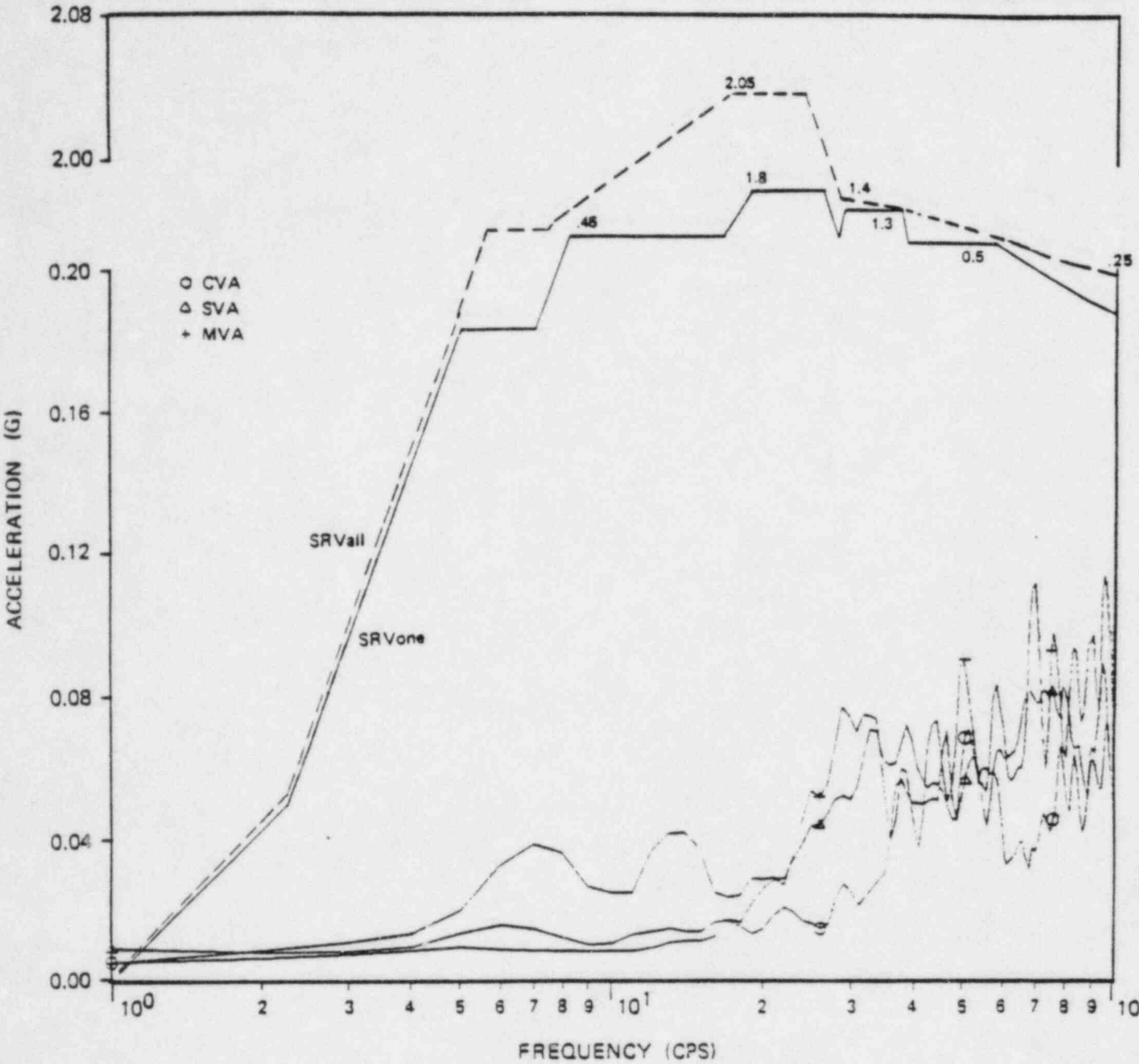


Figure 8.15

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A18
DRYWELL ELEV. 120'-10", TANGENTIAL

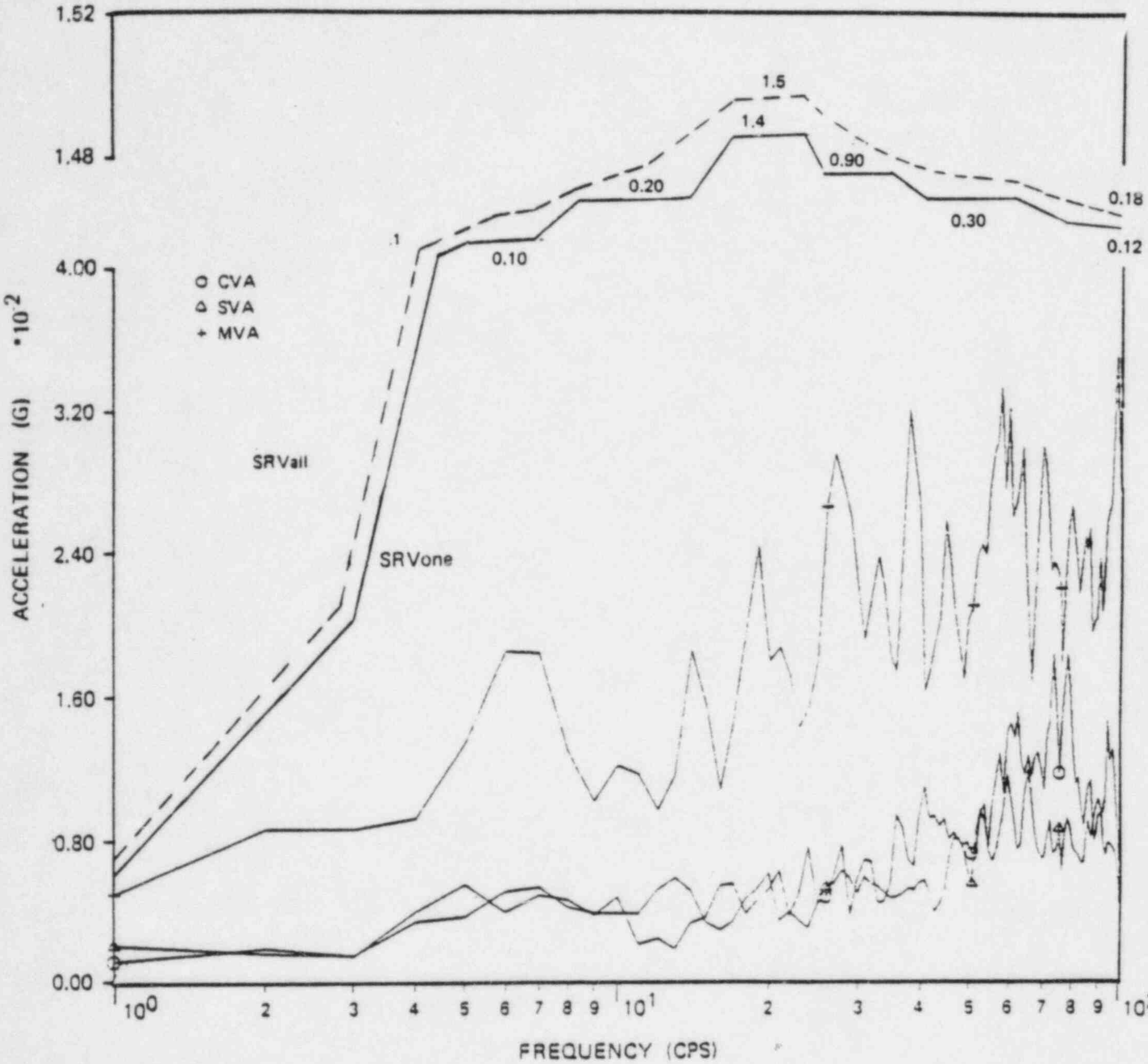


Figure 8.16

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A19
DRYWELL ELEV. 147'-7", RADIAL

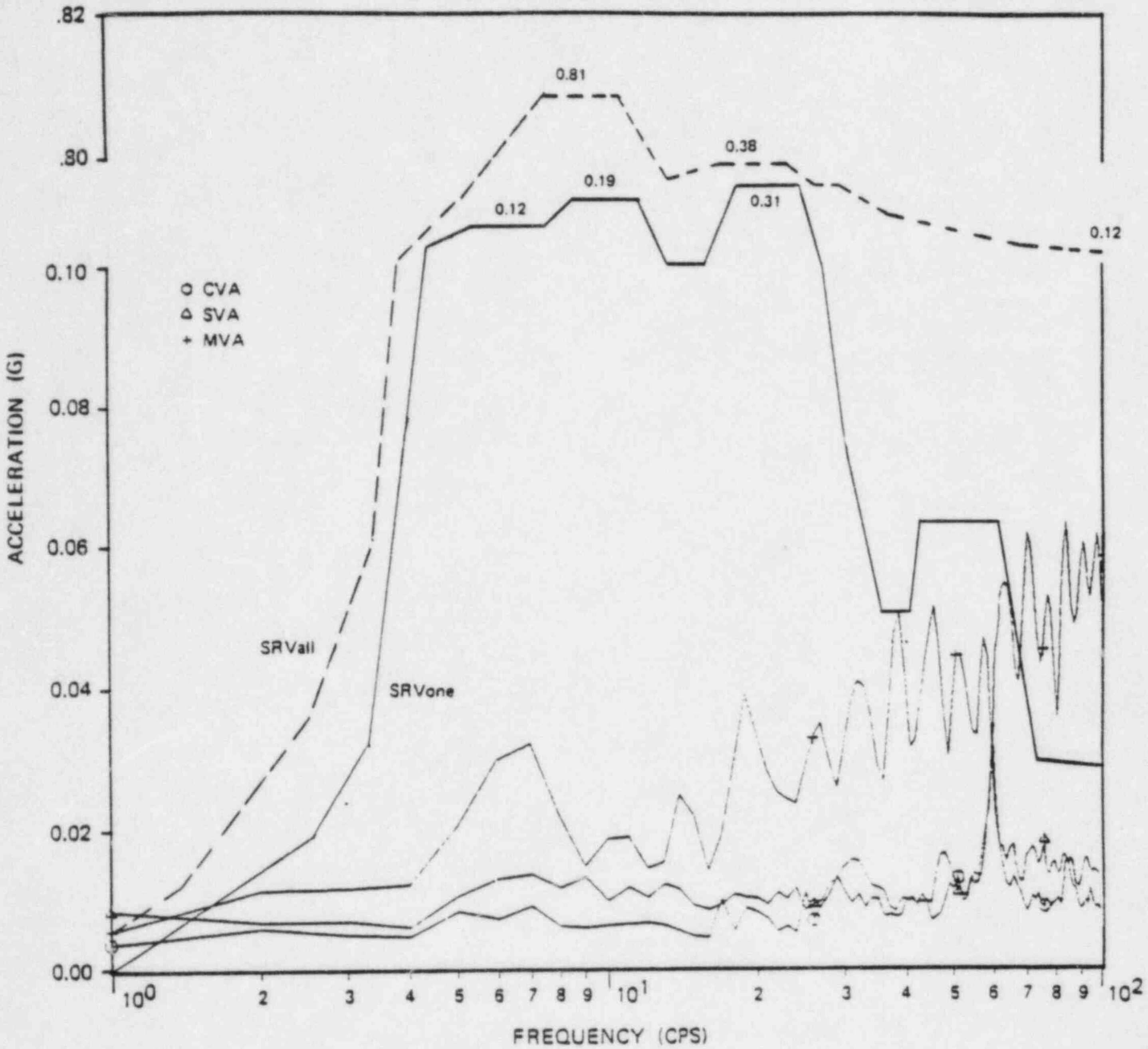


Figure 8.17

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A20
DRYWELL ELEV. 147'-7", VERTICAL

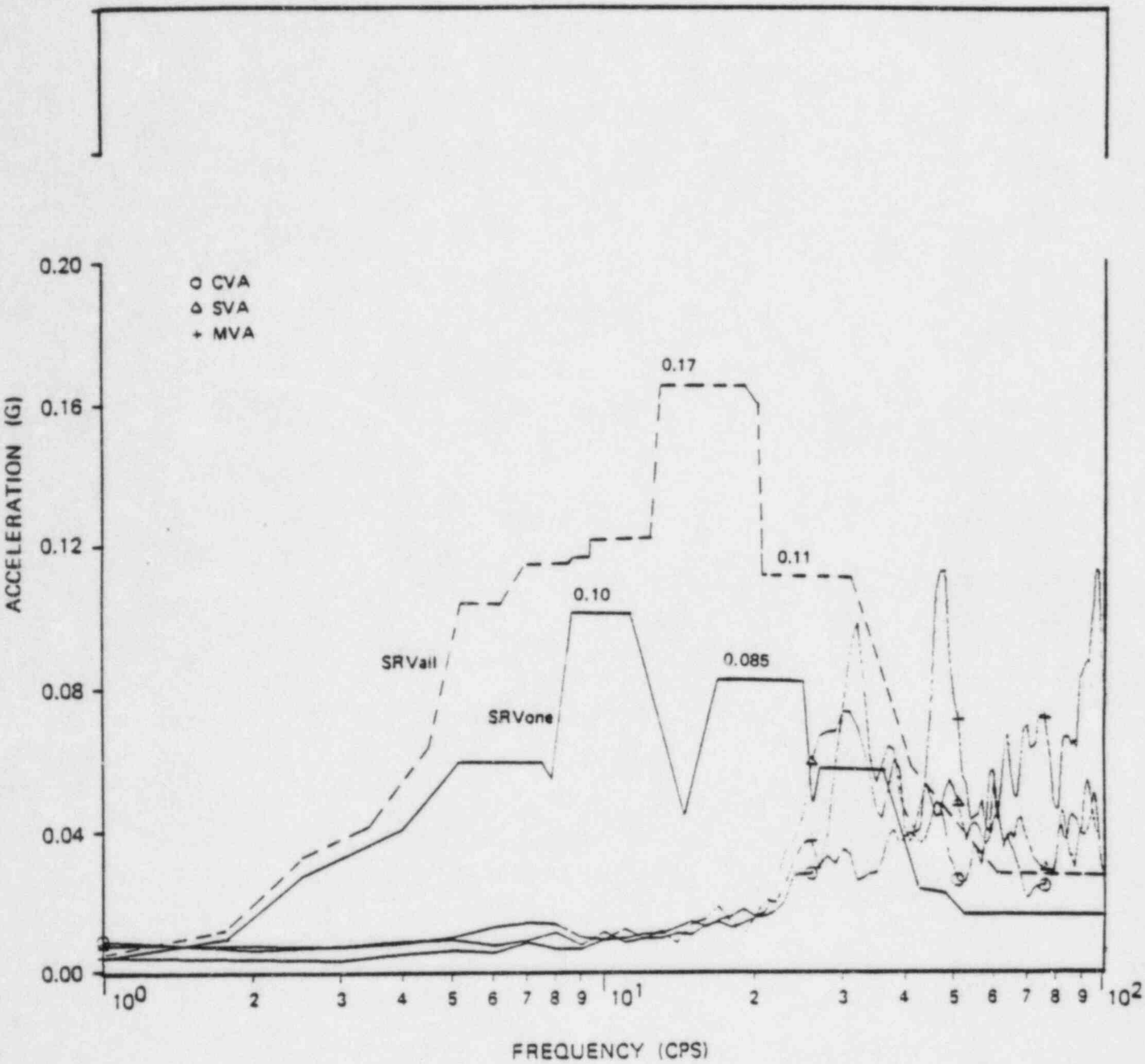


Figure 8.18

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A21
DRYWELL ELEV. 184'-6", RADIAL

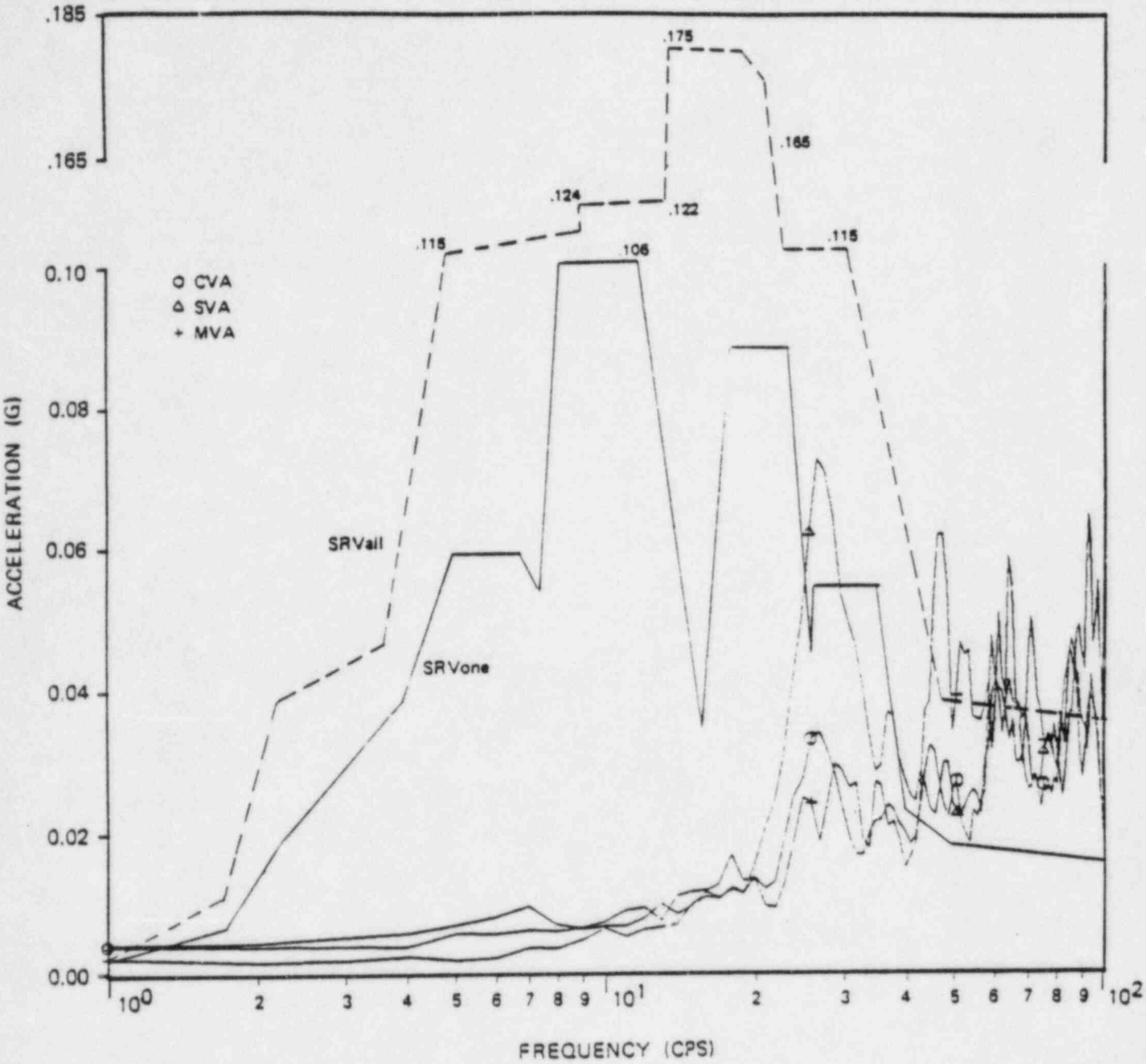


Figure 8.19

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A22
DRYWELL ELEV. 184'-6", TANGENTIAL

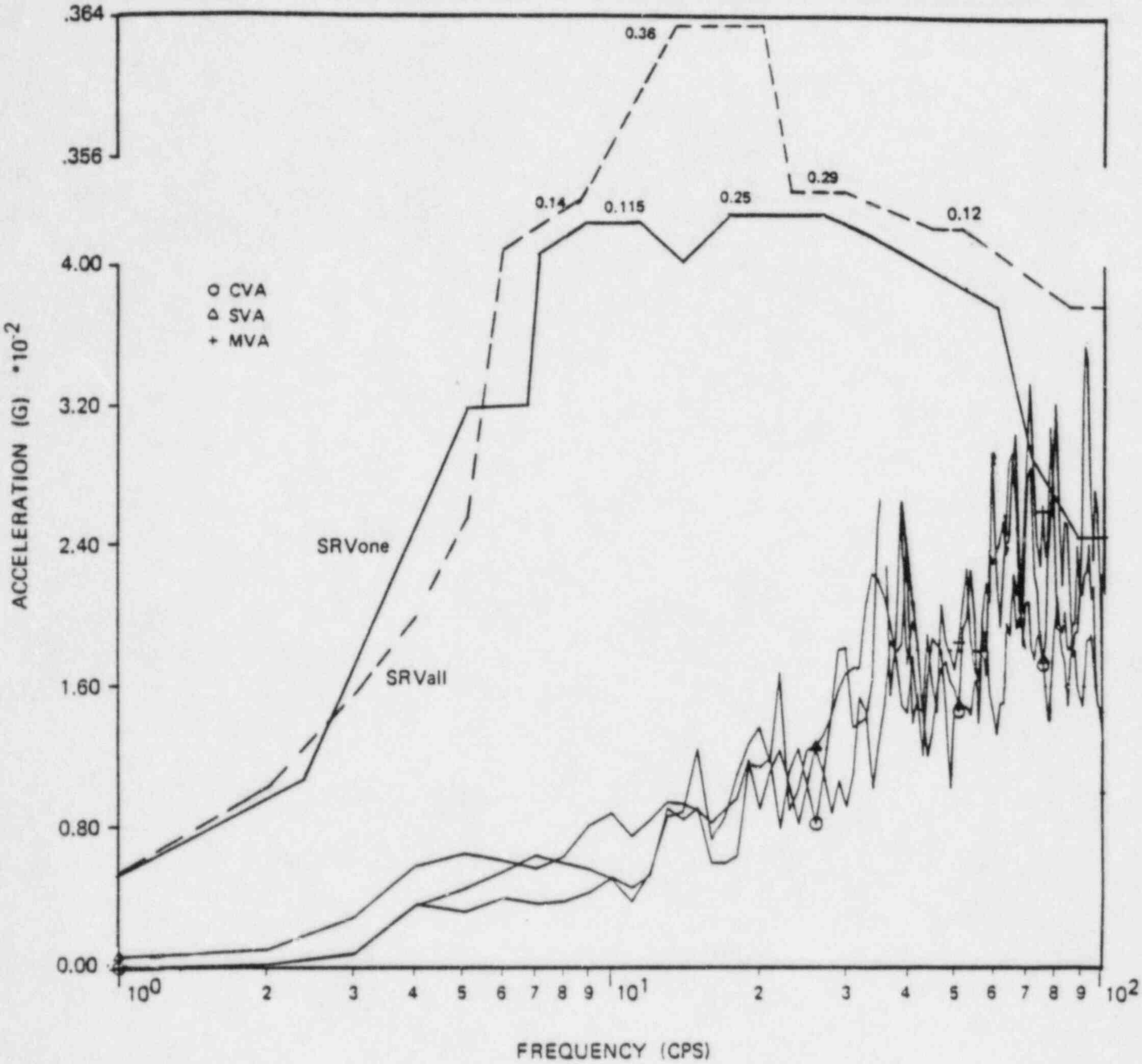


Figure 8.20

<u>ENVELOPE RESPONSE SPECTRA ACCELEROMETER A25</u>
<u>RPV PEDESTAL ELEV. 100'-9", RADIAL</u>

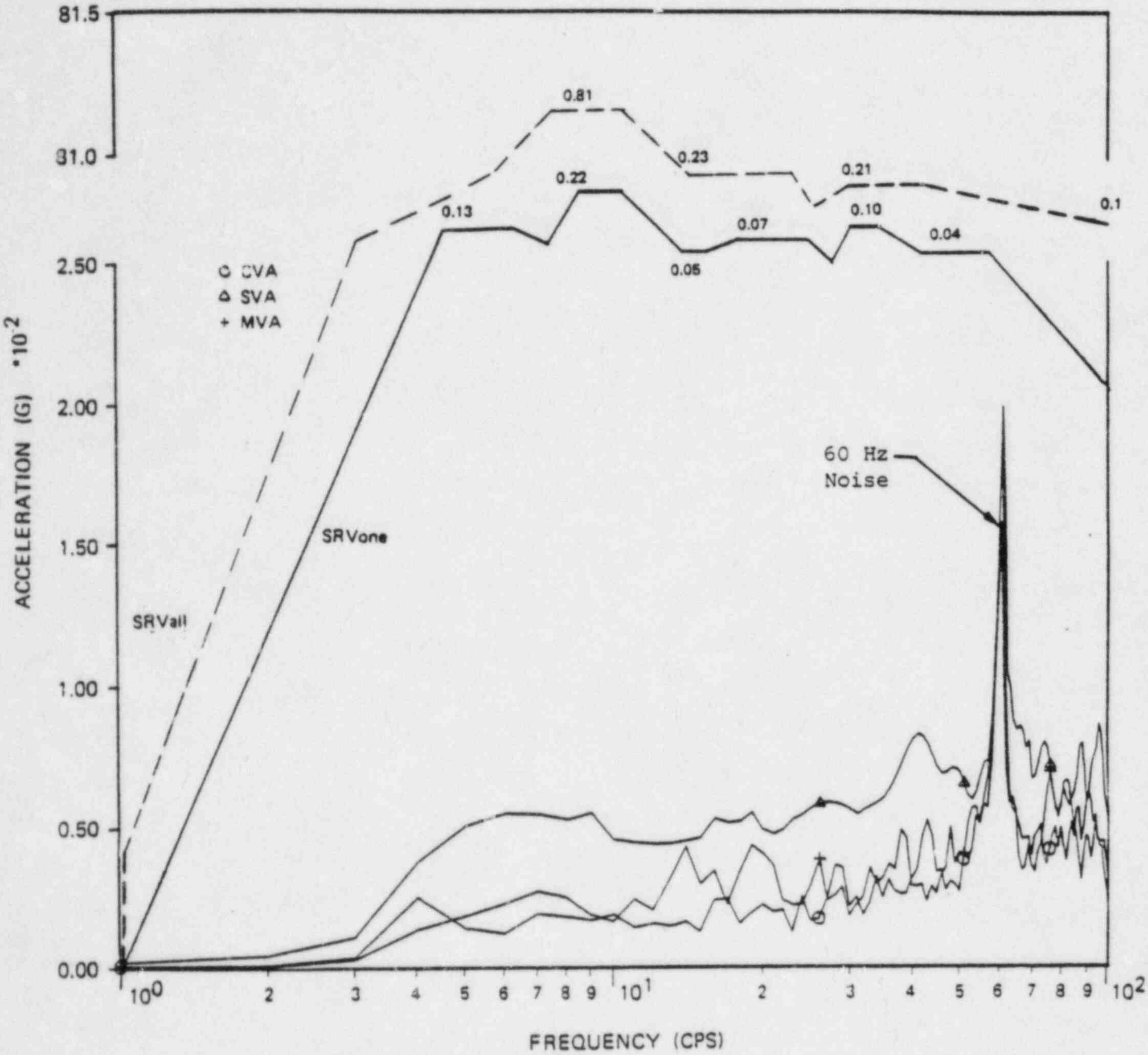


Figure 8.21

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A26
RPV PEDESTAL ELEV. 100'-9", VERTICAL

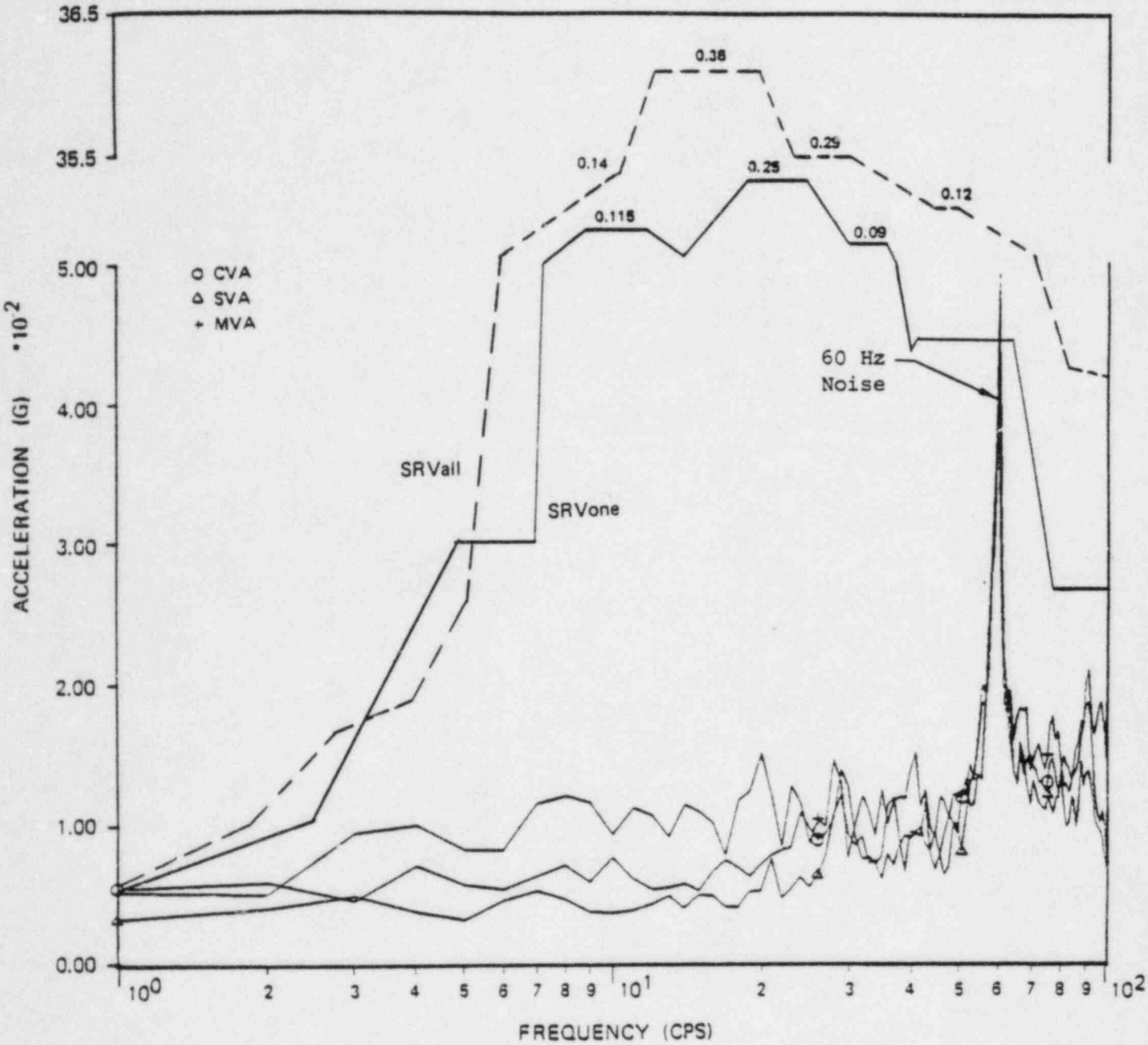


Figure 8.22

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A27
RPV PEDESTAL ELEV. 100-'9", RADIAL

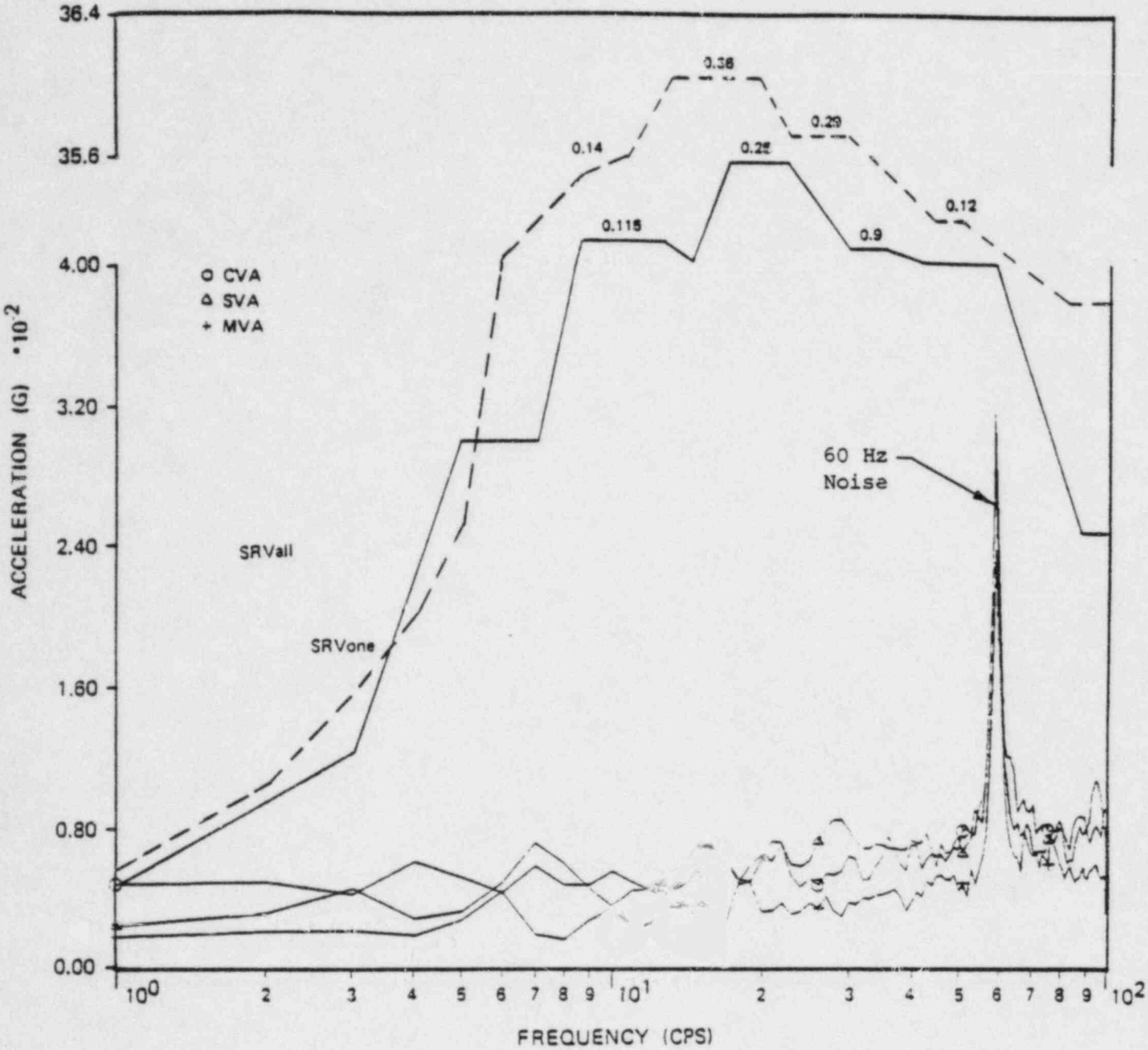


Figure 8.23

ENVELOPE RESPONSE SPECTRA ACCELEROMETER A28
RPV PEDESTAL ELEV. 100'-9", TANGENTIAL

9.0 COMPARISON WITH KUOSHENG DATA

This section provides comparisons of the data collected during the Grand Gulf SRV discharge tests with the data collected during the SRV tests conducted at the Kuosheng Nuclear Power Station in August 1981, reported in Reference 10.

9.1 Suppression Pool Boundary Pressures

The Grand Gulf measured suppression pool boundary pressures reported in Section 7.1 are bounded by the Kuosheng measured results. Table 9.1 provides a comparison of the calculated 95-95, and design pressures for SVA, CVA and MVA for Kuosheng and Grand Gulf. Figure 9.1 through 9.12 provide typical Kuosheng measured SVA, CVA and MVA pressure time histories and power spectra density (PSD) plots. Comparing these with Figures 7.1 through 7.12 shows that the measured pressure traces have a similar form for both plants. The frequency content of both is also very similar; however, the amplitude of the high frequency initial air clearing spike is smaller for Grand Gulf. This is probably the result of the smaller taper angle in the quencher hub (Grand Gulf is 10.4° vs 17.1° for Kuosheng).

9.2 SRVDL and Quencher Internal Pressures

As described in Section 7.2 the unfiltered peak SRVDL pressure measured for SD1 is a 450 psi spike. A similar phenomenon was observed at Kuosheng but after filtering of data to 100 Hz this spike was reduced to 224 psi for a first actuation. The peak Grand Gulf pressure measured for MT70, equivalent to a CVA, was 282 psi compared to a peak of 179 psi for Kuosheng. The recorded

pressure trace for MT70 follows the same pattern measured at Kuosheng and is well below the 550 psi design pressure.

The peak internal quencher pressure for Kuosheng was 160 psi compared to 242 psi measured for MT70 at Grand Gulf. These pressures are much lower than the 550 psi design pressure.

9.3 Strain Data

Figures 9.13 and 9.14 provide typical measured Kuosheng strain time histories. Because of the widely different distribution of strain gauges and differences in quencher support designs, it is not possible to draw a direct comparison of strain measurements for identical items. The recorded strains for the Kuosheng quencher support were approximately 15% of predicted values compared to the peak MVA recorded Grand Gulf strain which is approximately 45% of predicted.

Submerged structure piping stresses, converted from strains, measured at Kuosheng range from 160 psi to 760 psi compared to peak calculated stresses at Grand Gulf of 410 psi.

The measured strain data for both Kuosheng and Grand Gulf show similar trends. Measured values are small compared to expected values and are insignificant when compared to material code allowables.

9.4 Accelerometer Data

Figure 9.15 through 9.24 provide a comparison of accelerometer response spectra data collected from the

Kuosheng and Grand Gulf tests. These figures show the single valve design spectra for Kuosheng and Grand Gulf, the single valve first actuation SRV test spectra for Kuosheng and the envelope spectra for all tests (SVA, CVA, MVA) for Grand Gulf.

Review of these figures shows that in most cases the SRV test results for all tests at Grand Gulf are similar in shape and magnitude to the SVA results from Kuosheng. In a few cases the Grand Gulf measured test spectra exceeds the Kuosheng test spectra and the Grand Gulf design spectra in the region above 60 Hz. However, it is obvious from the measured equipment response, at Grand Gulf, which is typically an order of magnitude less than expected, that these exceedances do not have any significance in relation to the Grand Gulf equipment design.

9.5 Summary

The data collected during the Grand Gulf SRV test program is similar to the data collected at Kuosheng. The much larger Kuosheng program provides a good data base on which to verify acceptability of the Grand Gulf design.

Table 9.1

COMPARISON OF SUPPRESSION POOL BOUNDARY PRESSURES (PSID)

		Grand Gulf	Kuosheng
SVA	95-95	+4.98/-5.51	+7.62/-5.71
	max/min(1)	+4.63/-5.78	+12.05/-7.15
	Design	+18.2/-7.7	+16.6/-7.38
CVA	95-95	+8.52/-4.62	(2)
	max/min	+7.47/-4.47	+9.81/-9.44
	Design	+18.2/-7.7	+16.6/-7.38
MVA	95-95	+5.53/-3.55	(3)
	max/min	+4.06/-2.60	+10.11/-8.89
	Design	+10.3/-6.4	+9.85/-6.15

NOTES:

1. Max/min provide the peak positive and negative pressures for all tests.

2. 95-95 pressure was not calculated for Kuosheng. Peak measured pressures were +9.81/-9.44 psid for Kuosheng compared to +7.47/-4.47 psid for Grand Gulf.

3. 95-95 pressure was not calculated for Kuosheng. Peak measured pressures were +10.11/-8.89 psid for Kuosheng compared to +4.06/-2.60 psid for Grand Gulf.

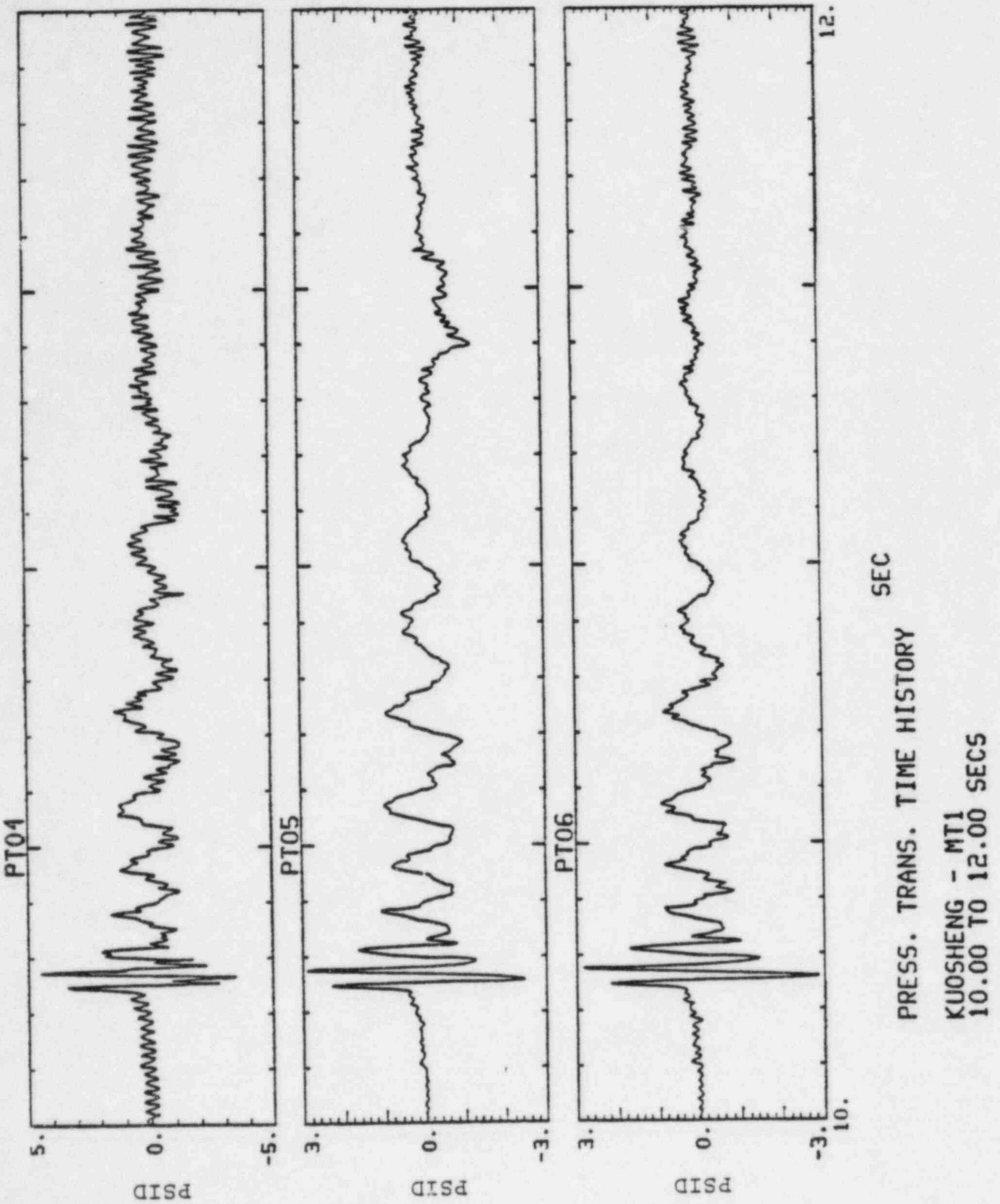


Figure 9.1

TYPICAL KUOSHENG SVA PRESSURE TIME HISTORIES

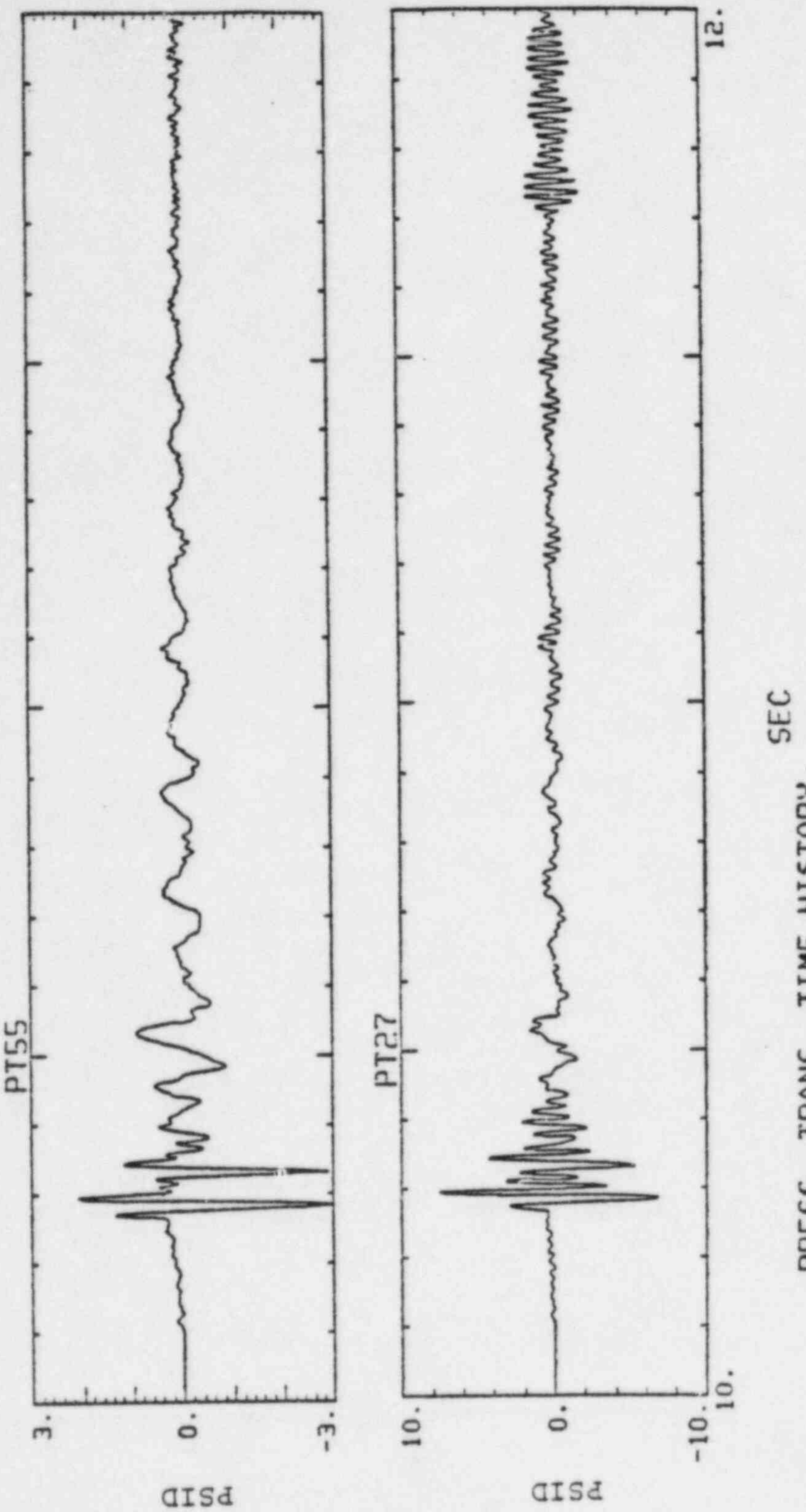


Figure 9.2

TYPICAL KUOSHENG SVA PRESSURE TIME HISTORIES

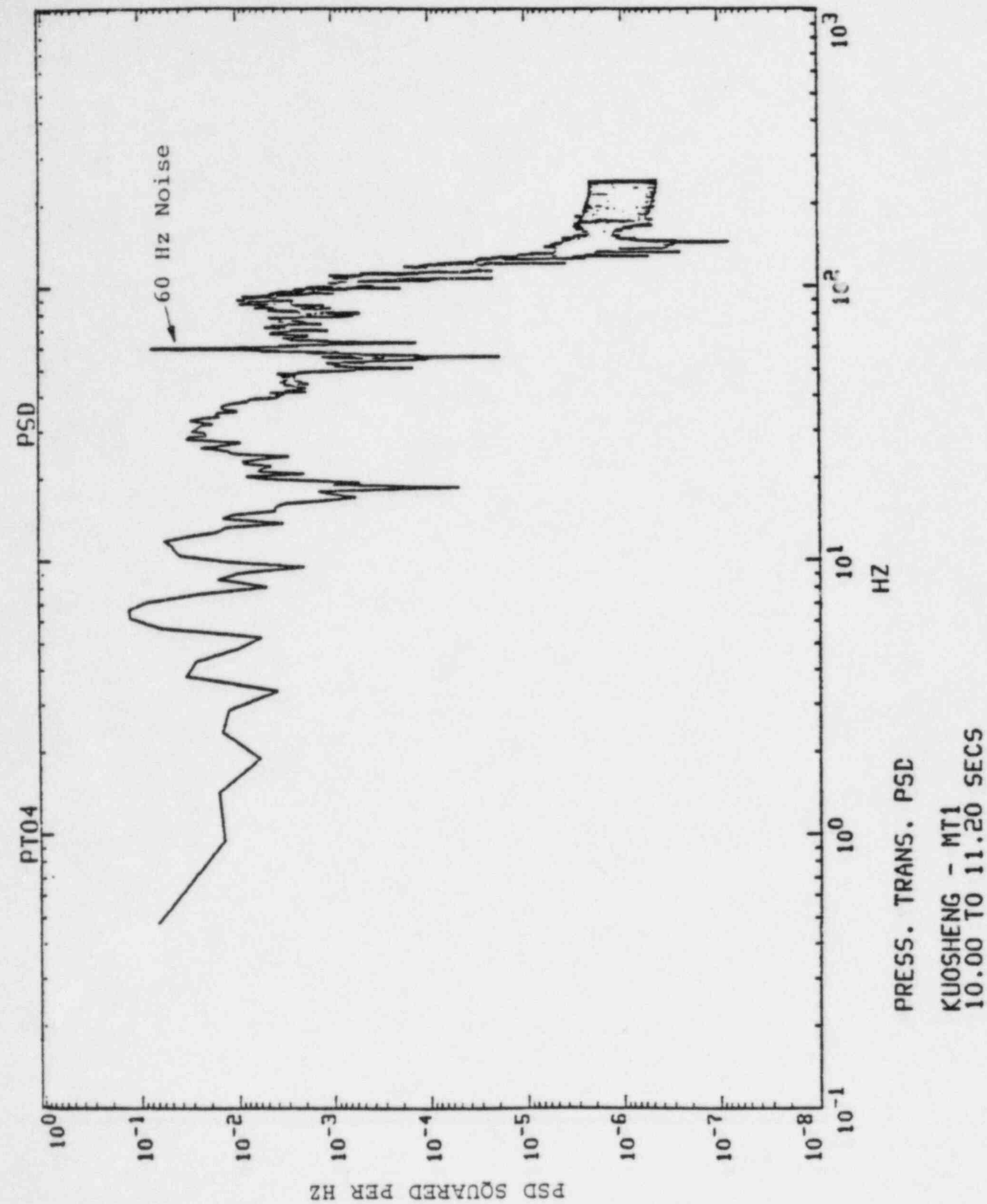


Figure 9.3

<u>TYPICAL KUOSHENG SVA PRESSURE PSD</u>

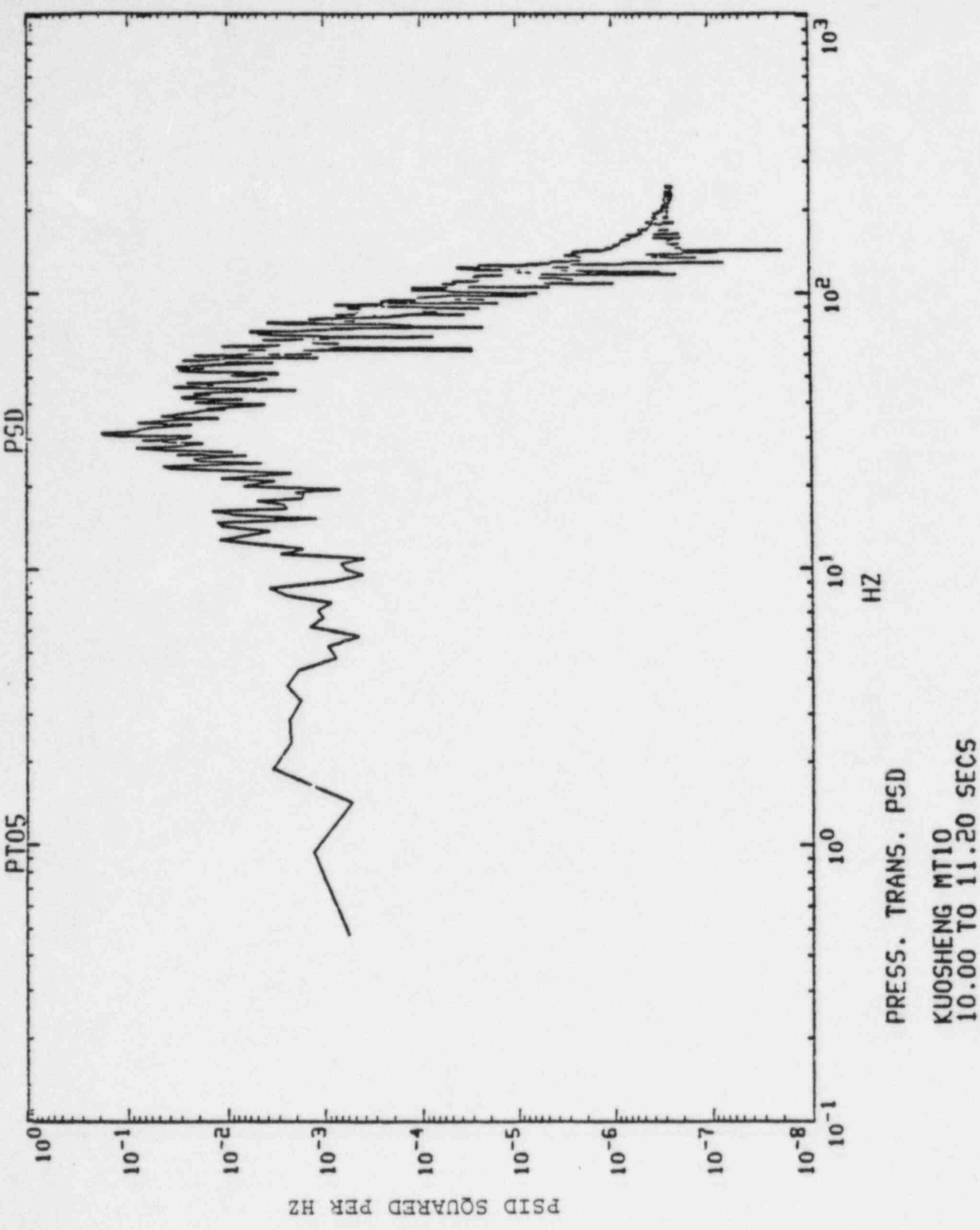


Figure 9.4

TYPICAL KUOSHENG SVA PRESSURE PSD

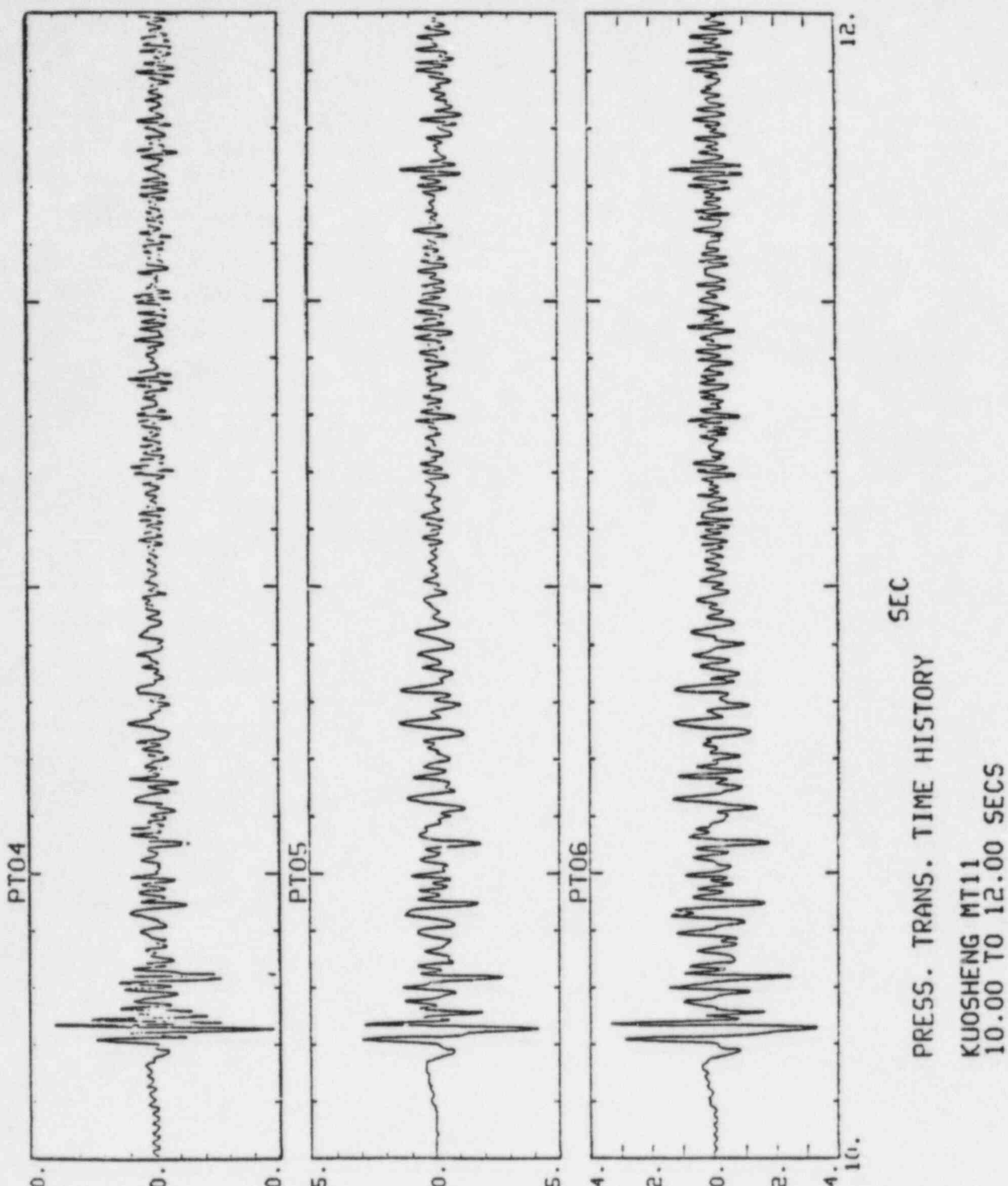


Figure 9.5

TYPICAL KUOSHENG CVA PRESSURE TIME HISTORY

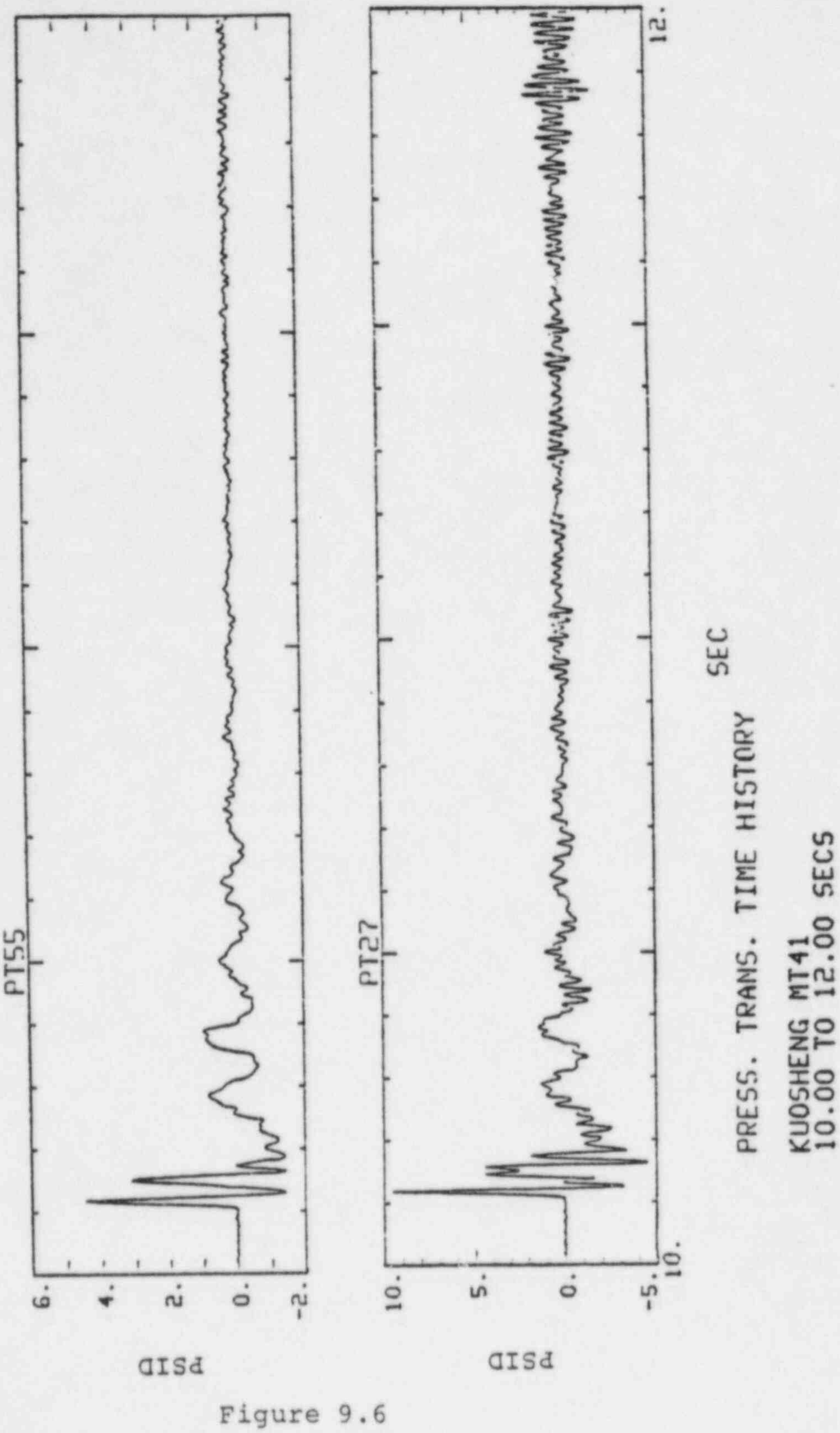


Figure 9.6

TYPICAL KUOSHENG CVA PRESSURE TIME HISTORY

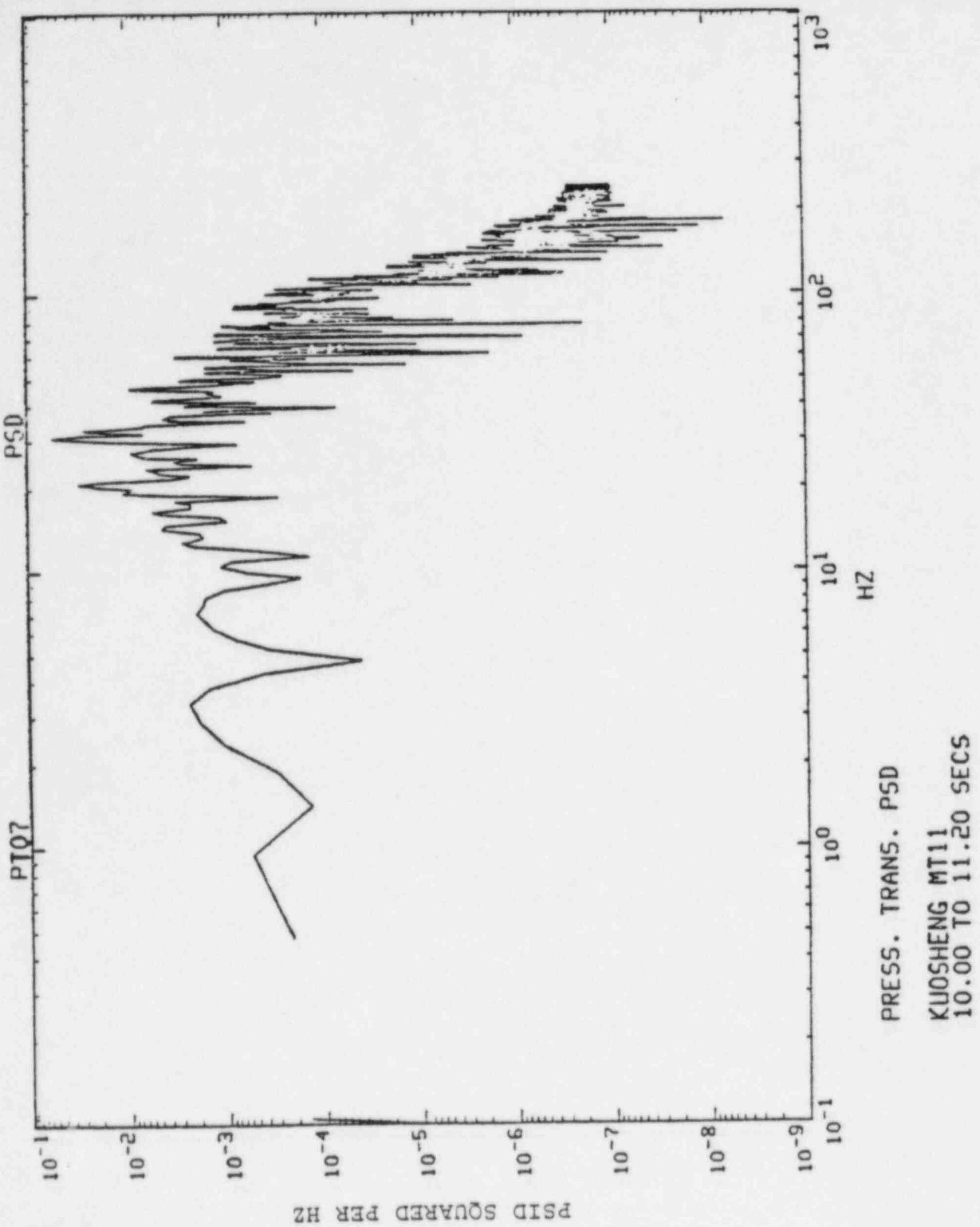


Figure 9.7

TYPICAL KUOSHENG CVA PRESSURE PSD

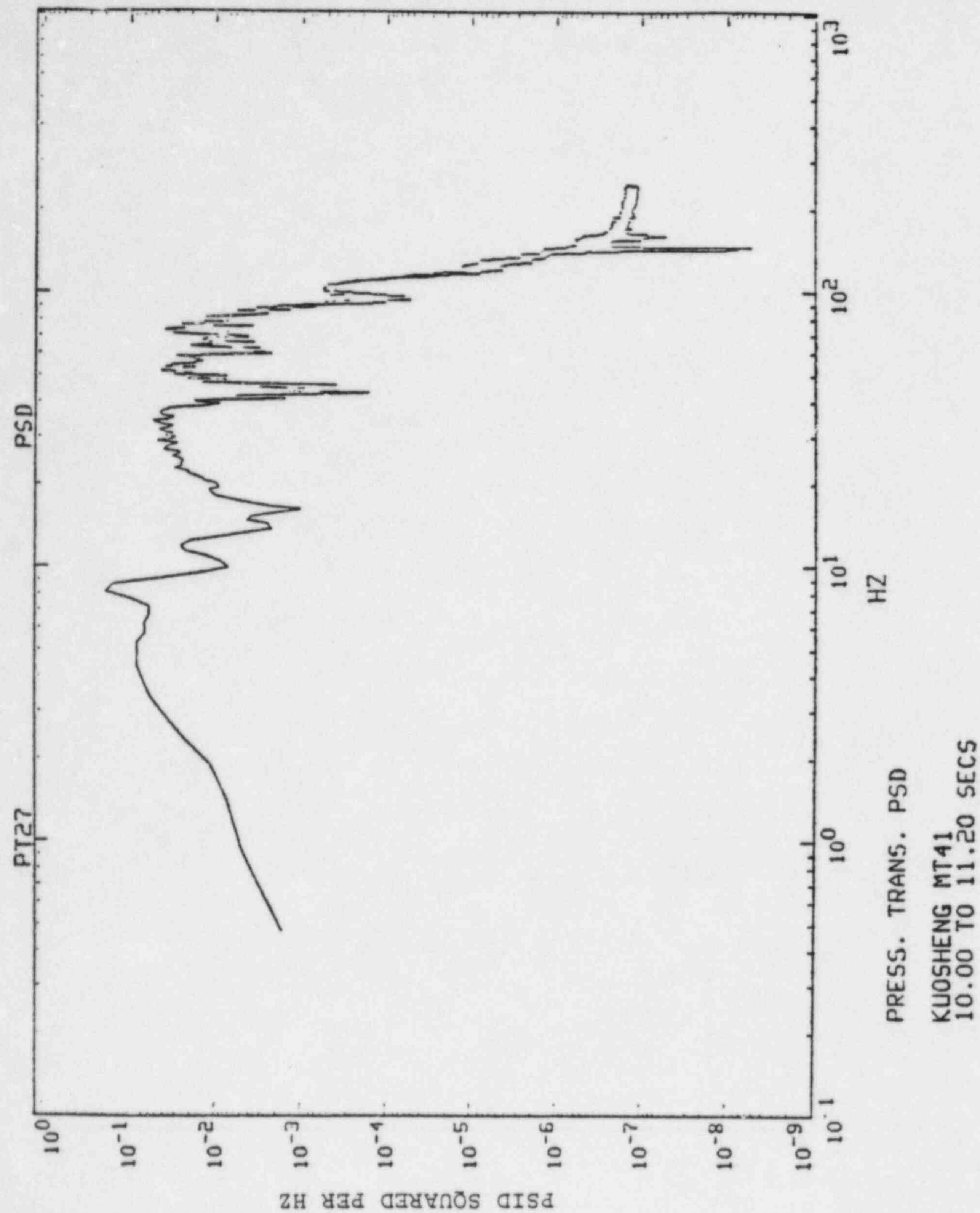


Figure 9.8

TYPICAL KUOSHENG CVA PRESSURE PSD

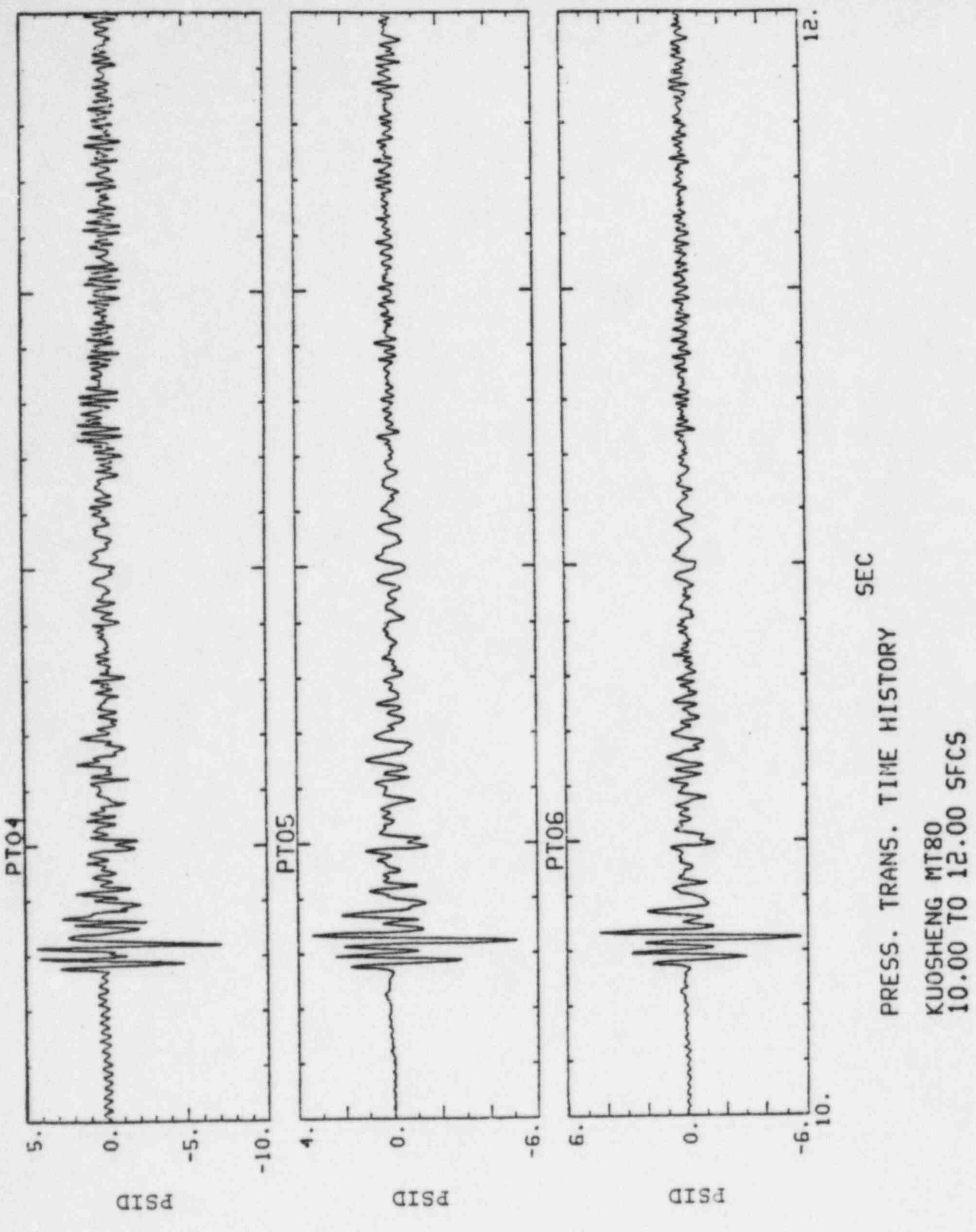


Figure 9.9

TYPICAL KUOSHENG MVA PRESSURE TIME HISTORY

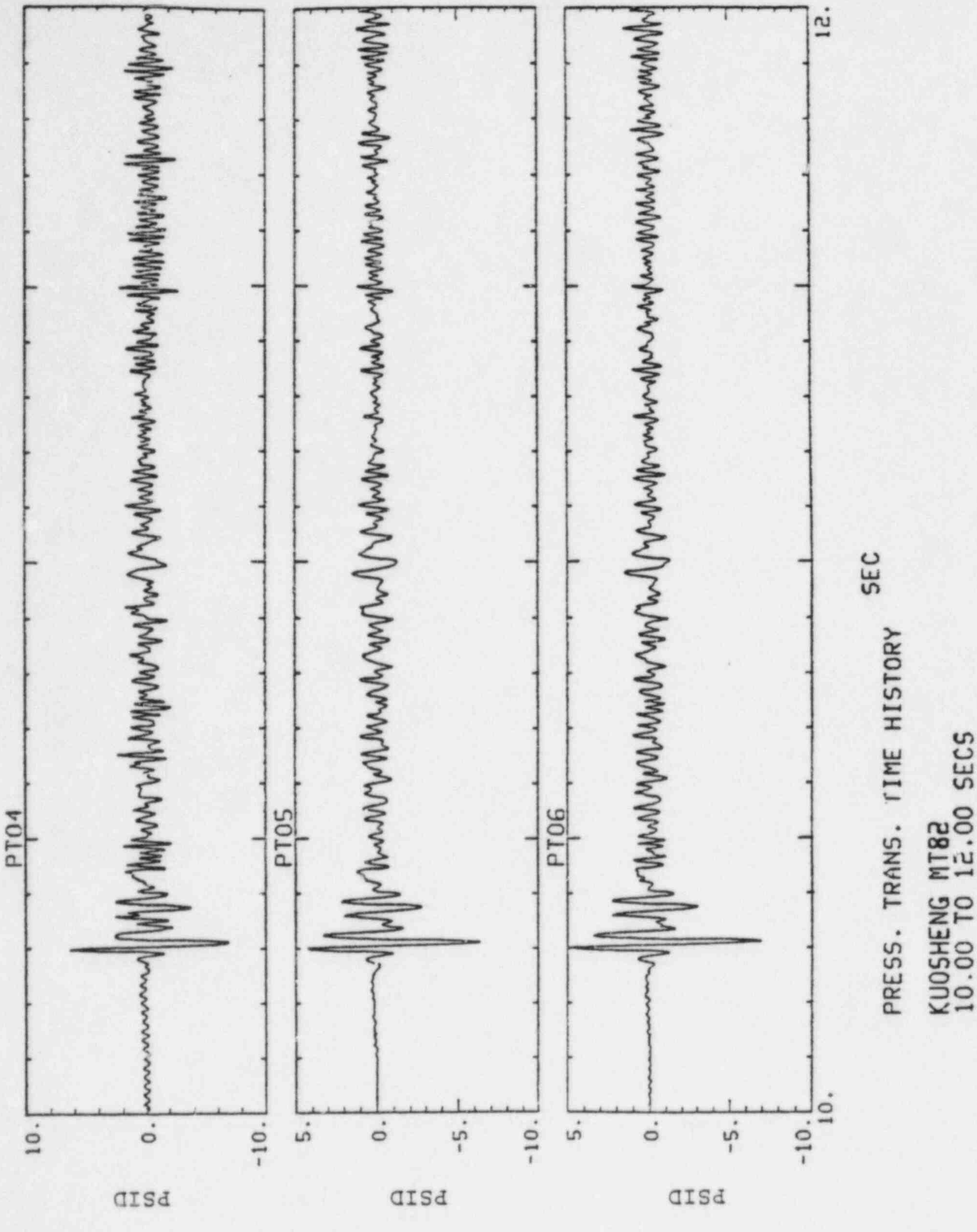


Figure 9.10

TYPICAL KUOSHENG MVA PRESSURE TIME HISTORY

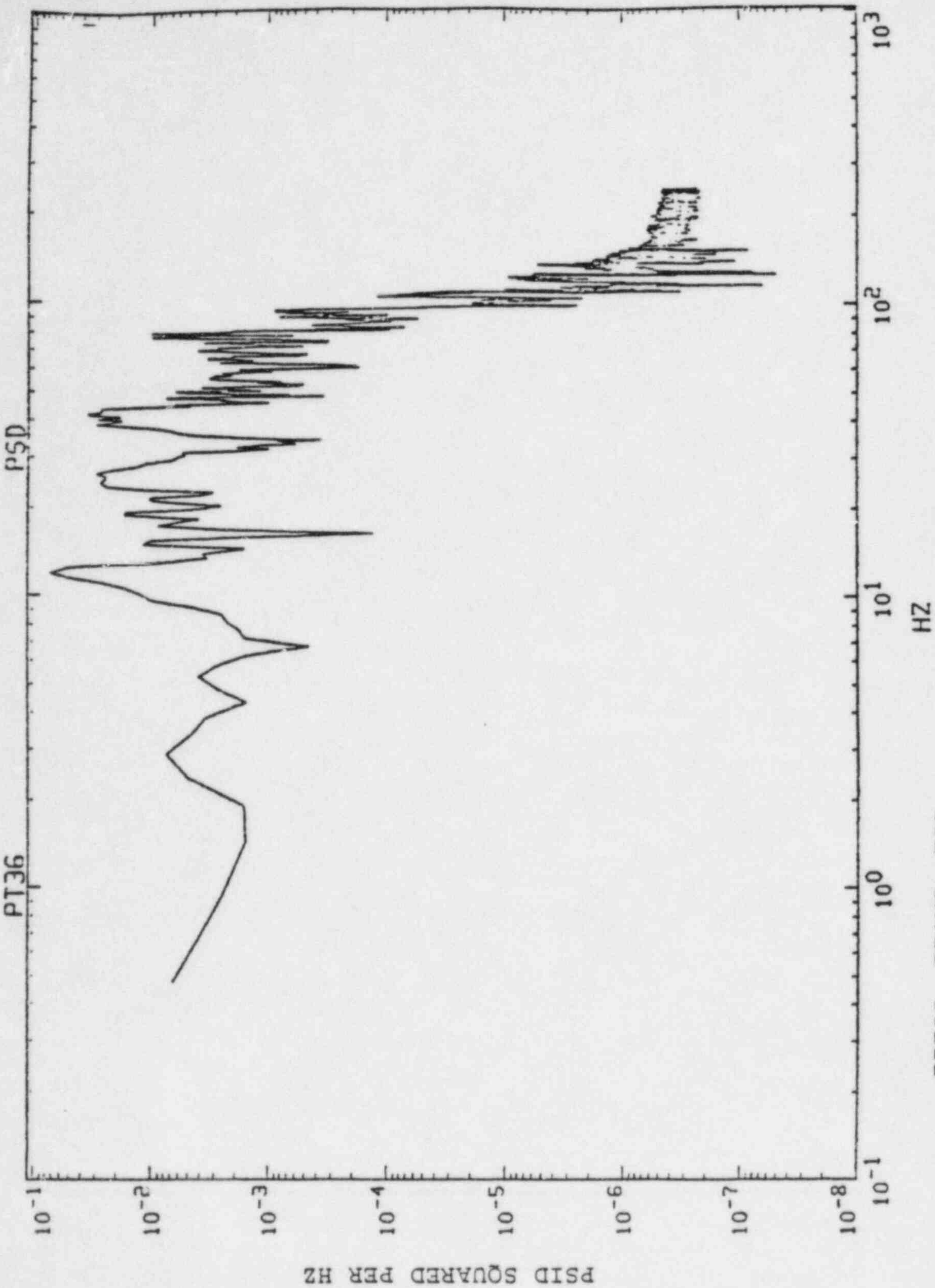


Figure 9.11

TYPICAL KUOSHENG MVA PRESSURE PSD

nutech ENGINEERS

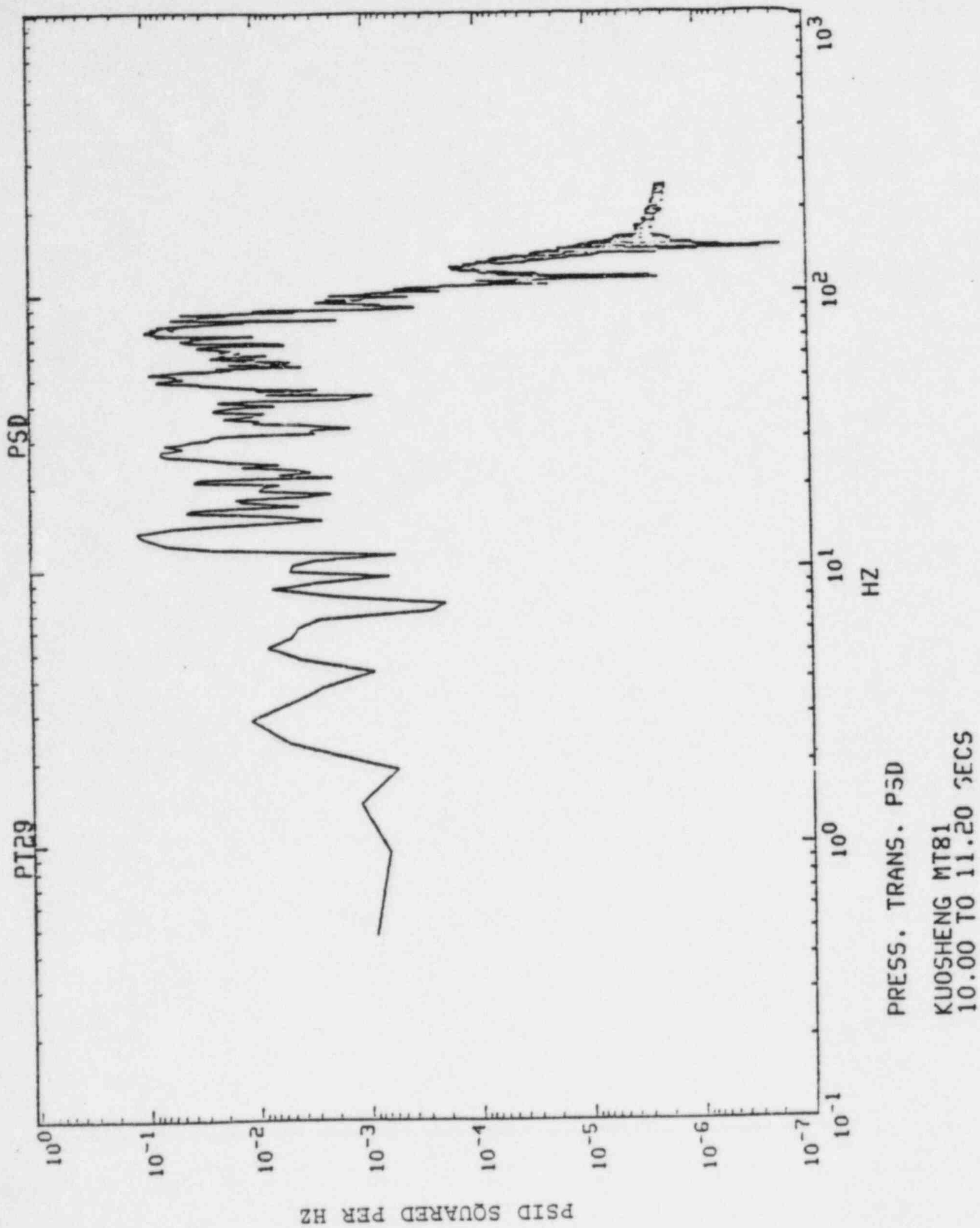


Figure 9.12

<u>TYPICAL KUOSHENG MVA PRESSURE PSD</u>

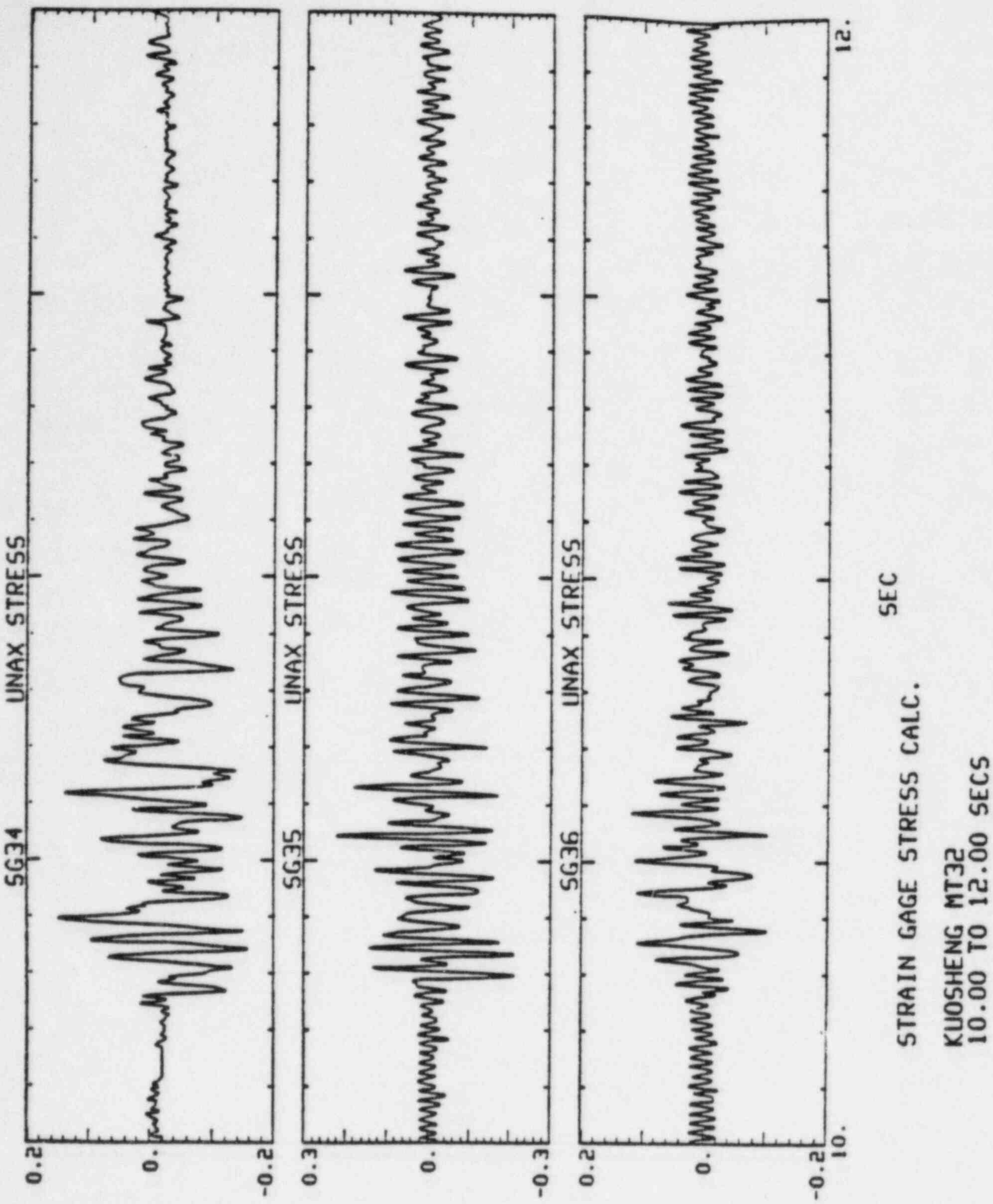


Figure 9.13

TYPICAL KUOSHENG STRAIN TIME HISTORY

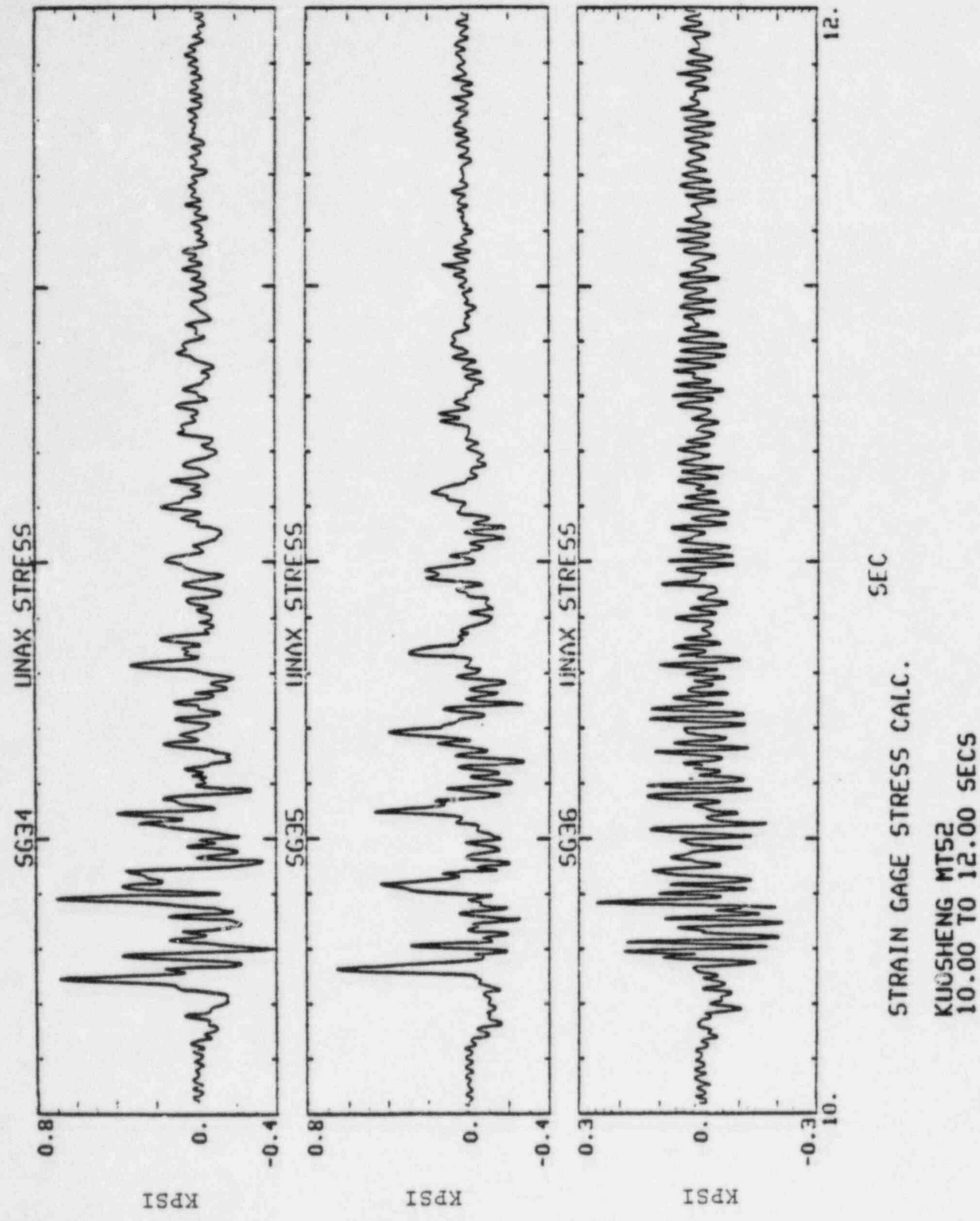


Figure 9.14

TYPICAL KUOSHENG STRAIN TIME HISTORY

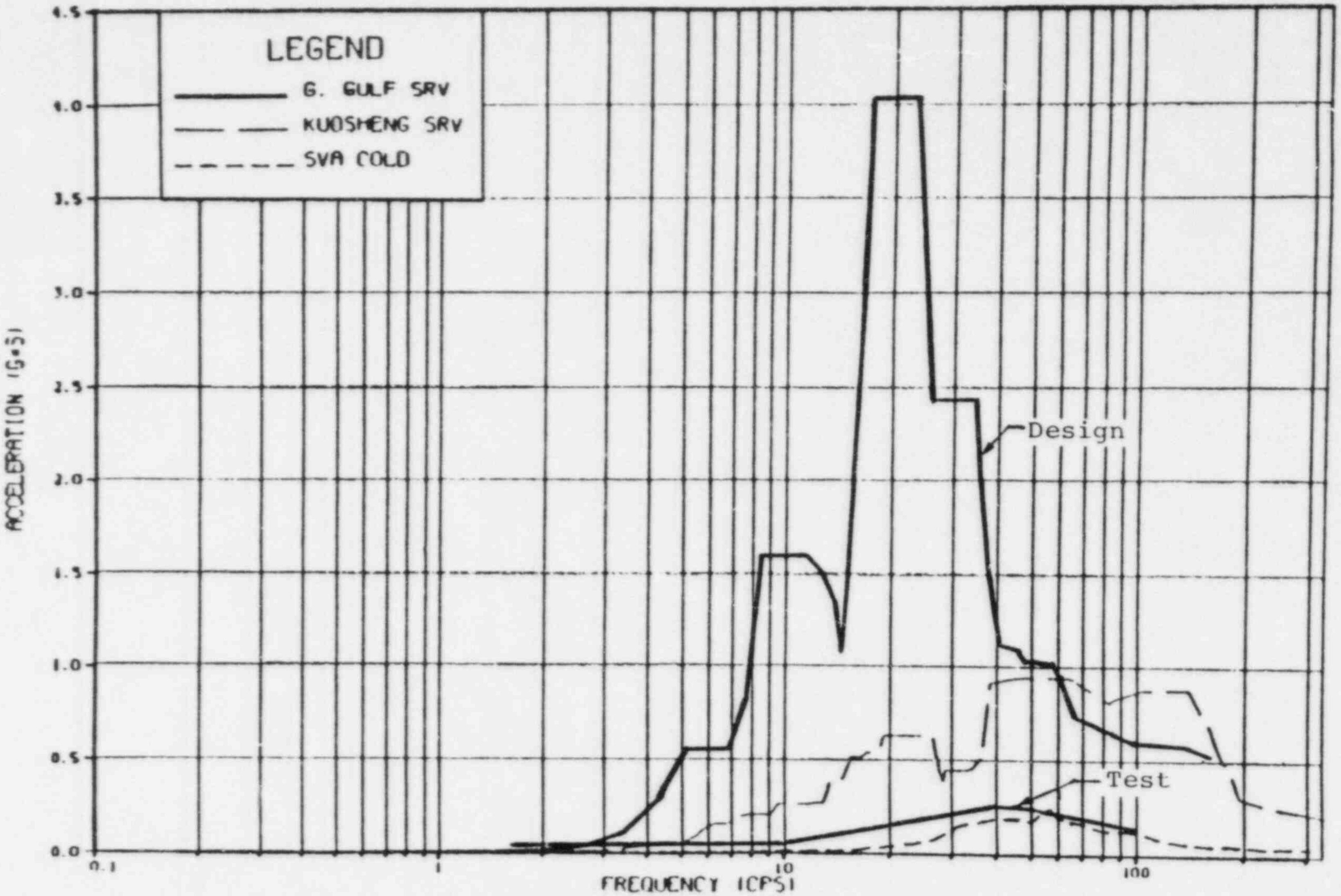


Figure 9.15

RESPONSE SPECTRA COMPARISON - GRAND GULF TO KUOSHENG
ACCELEROMETER A3, CONTAINMENT EL. 109.17, HORIZONTAL

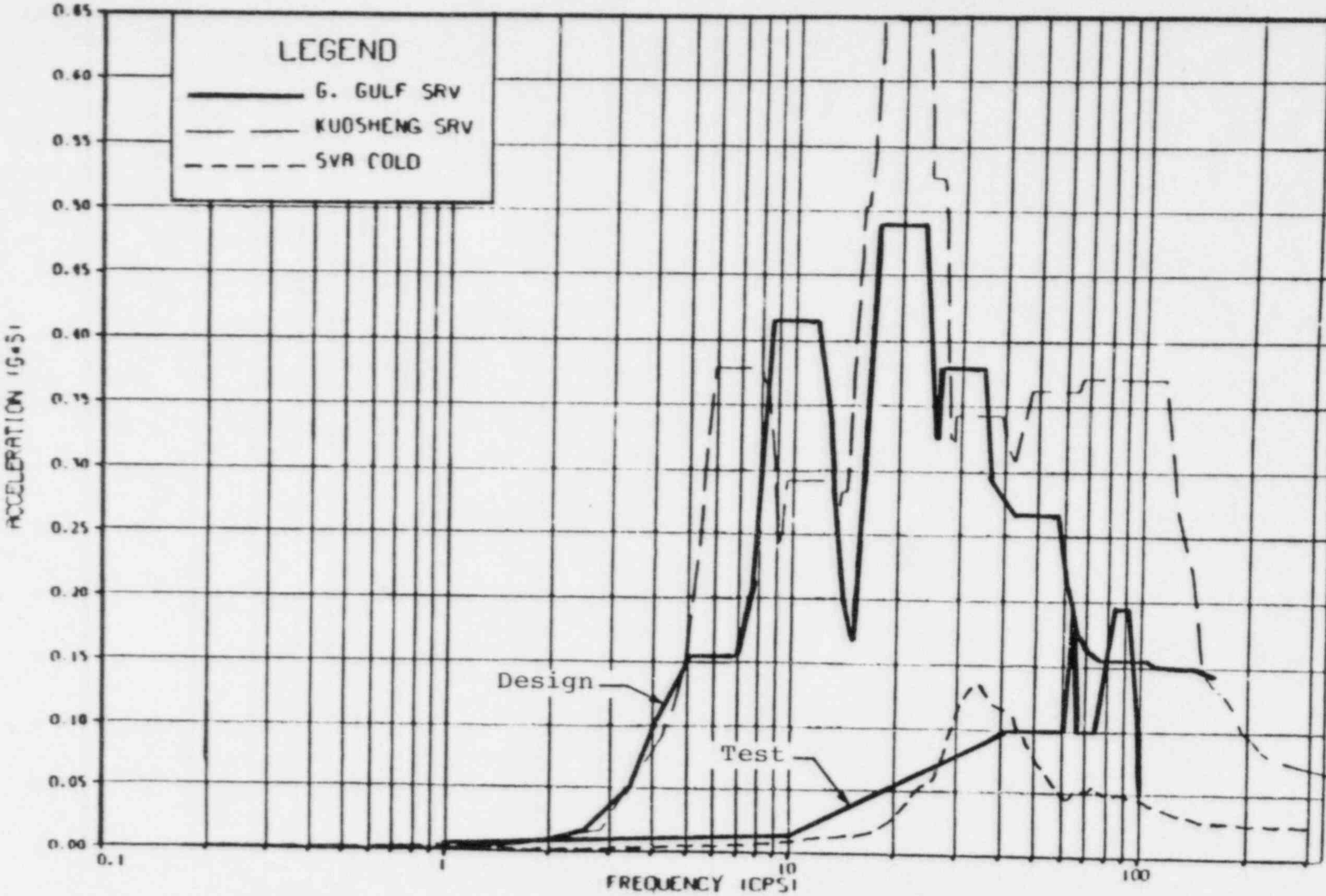


Figure 9.16

RESPONSE SPECTRA COMPARISON - GRAND GULF TO KUOSHENG
ACCELEROMETER A4, CONTAINMENT EL. 109.17, VERTICAL

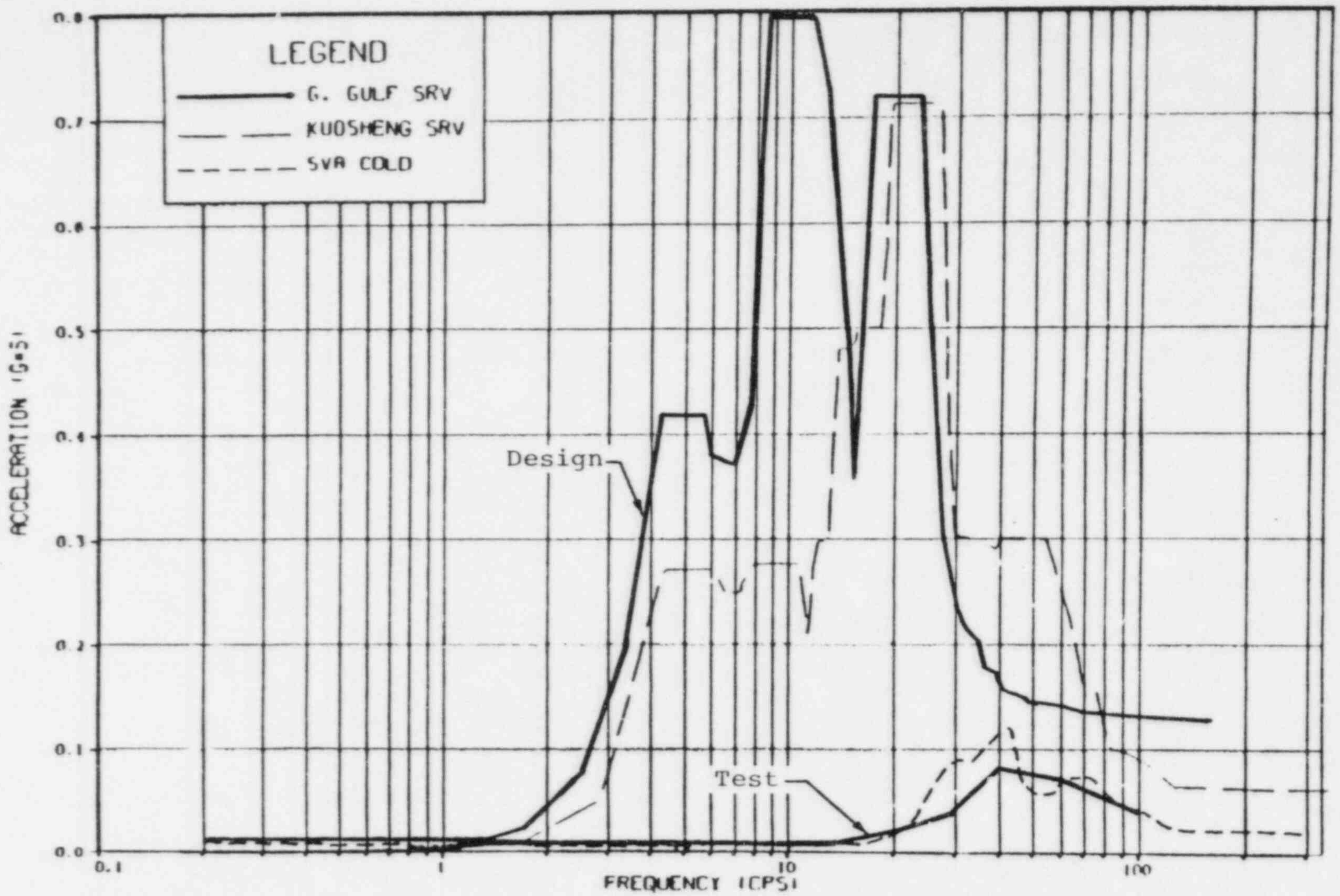


Figure 9.17

RESPONSE SPECTRA COMPARISON - GRAND GULF TO KUOSHENG
ACCELEROMETER A14, CONTAINMENT EL. 300.08, HORIZONTAL

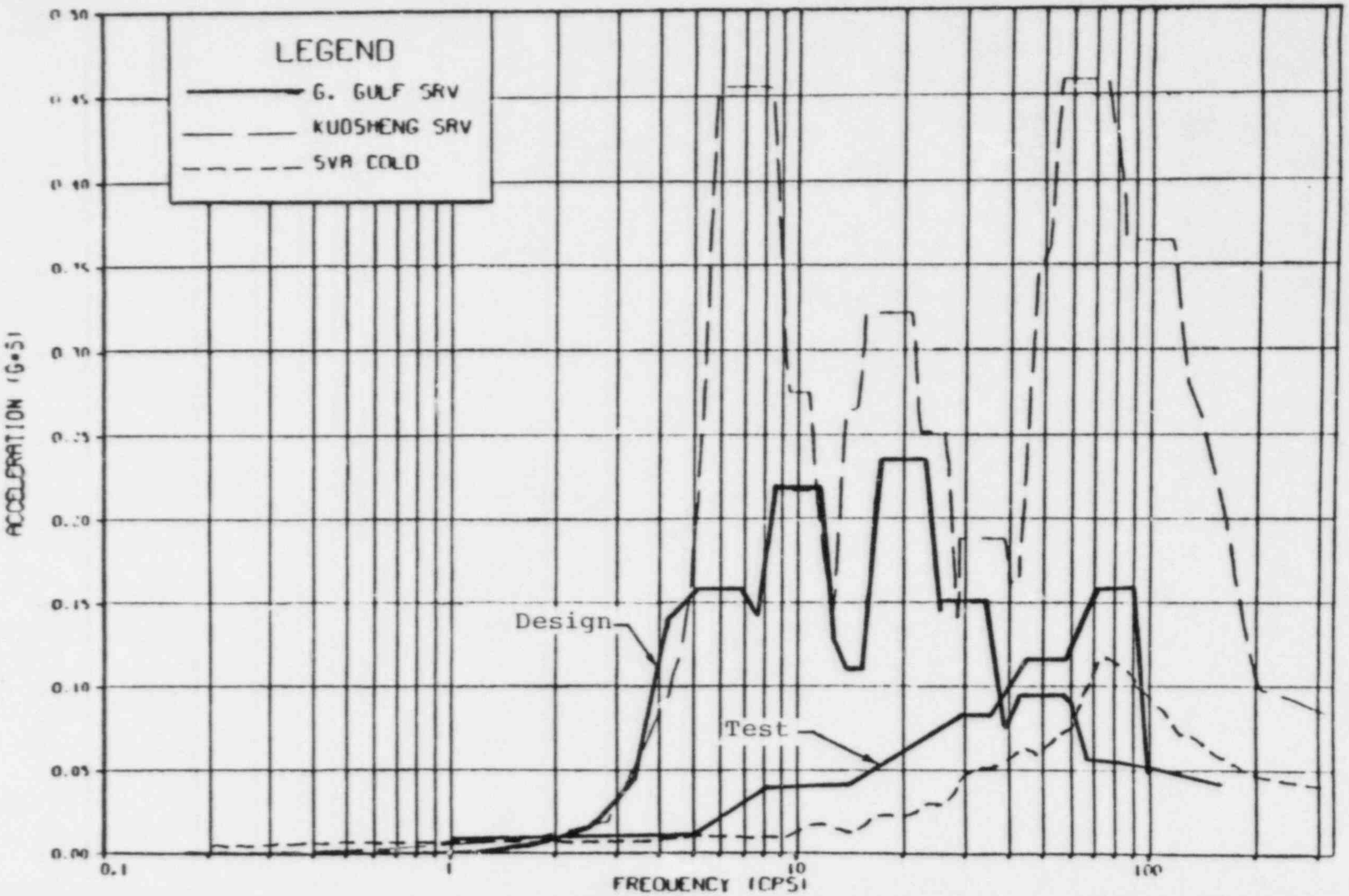


Figure 9.18

RESPONSE SPECTRA COMPARISON - GRAND GULF TO KUOSHENG
ACCLEROMETER A16, DRYWELL EL. 120.83, VERTICAL

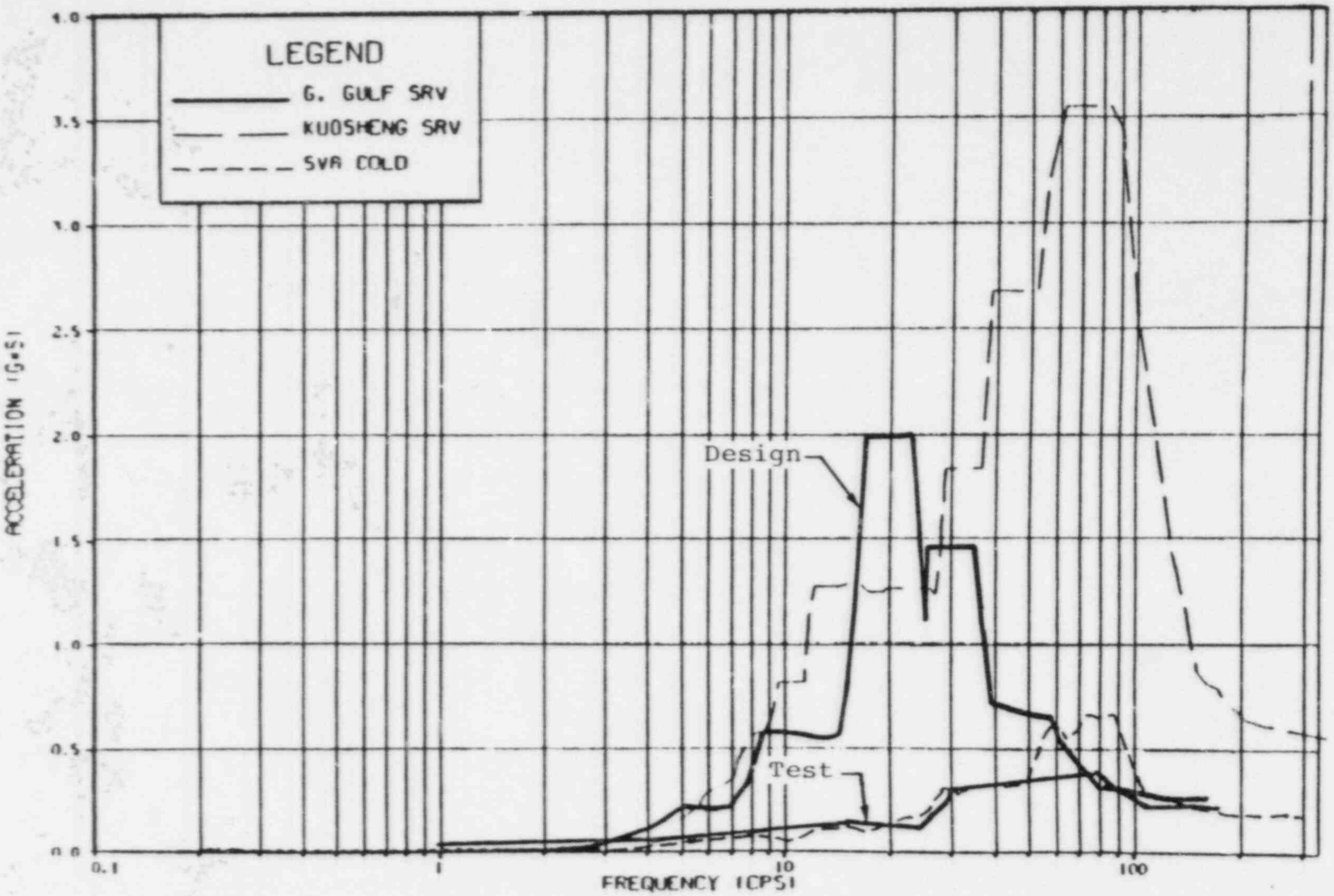


Figure 9.19

RESPONSE SPECTRA COMPARISON - GRAND GULF TO KUOSHENG
ACCELEROMETER A17/A18, DRYWELL EL. 120.83, HORIZONTAL

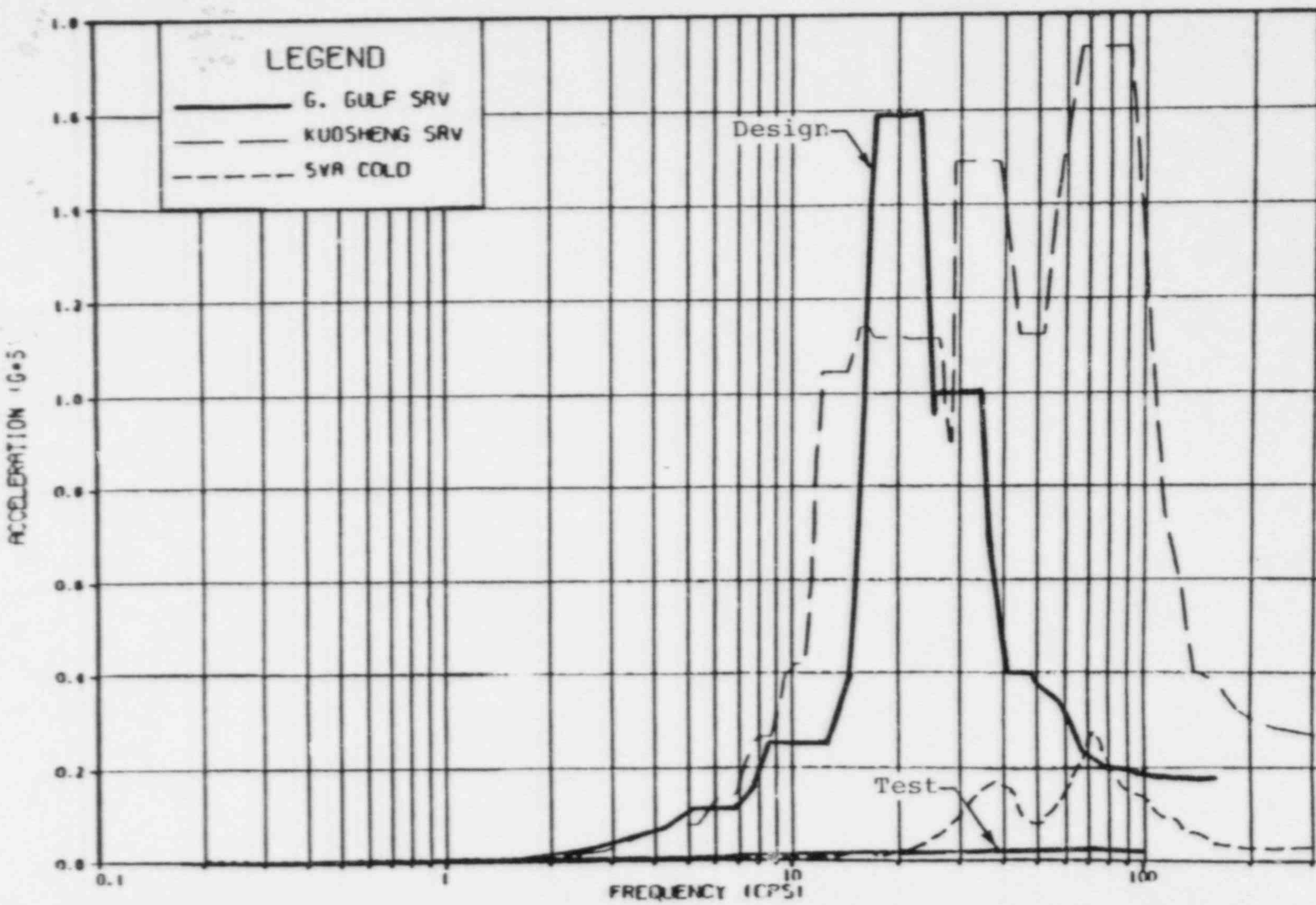


Figure 9.20

RESPONSE SPECTRA COMPARISON - GRAND GULF TO KUOSHENG ACCELEROMETER A19, DRYWELL EL. 147.58, HORIZONTAL

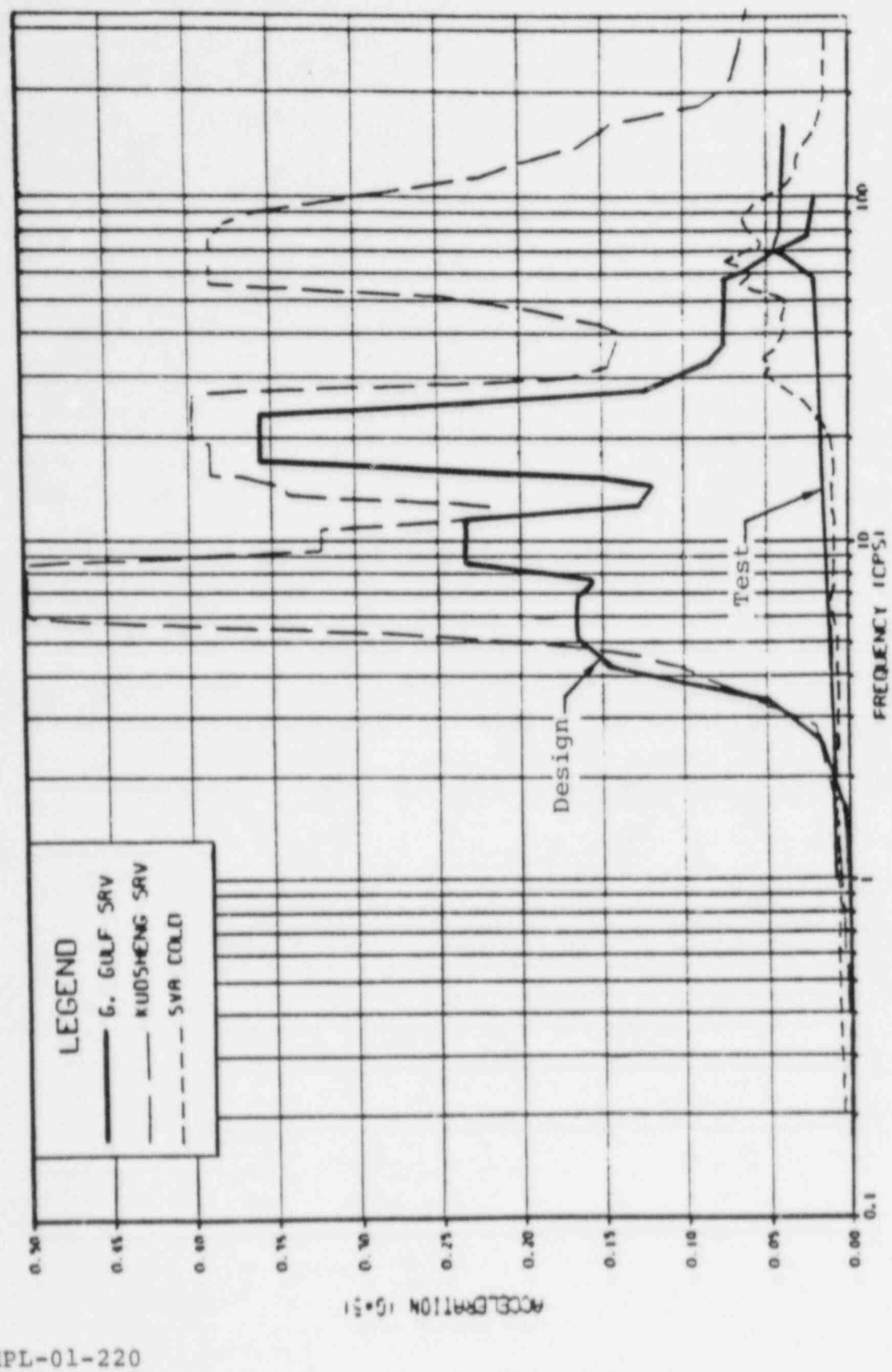


Figure 9.21

RESPONSE SPECTRA COMPARISON - GRAND GULF TO KUOSHENG
ACCELEROMETER A20, DRYWELL EL. 147.58, VERTICAL

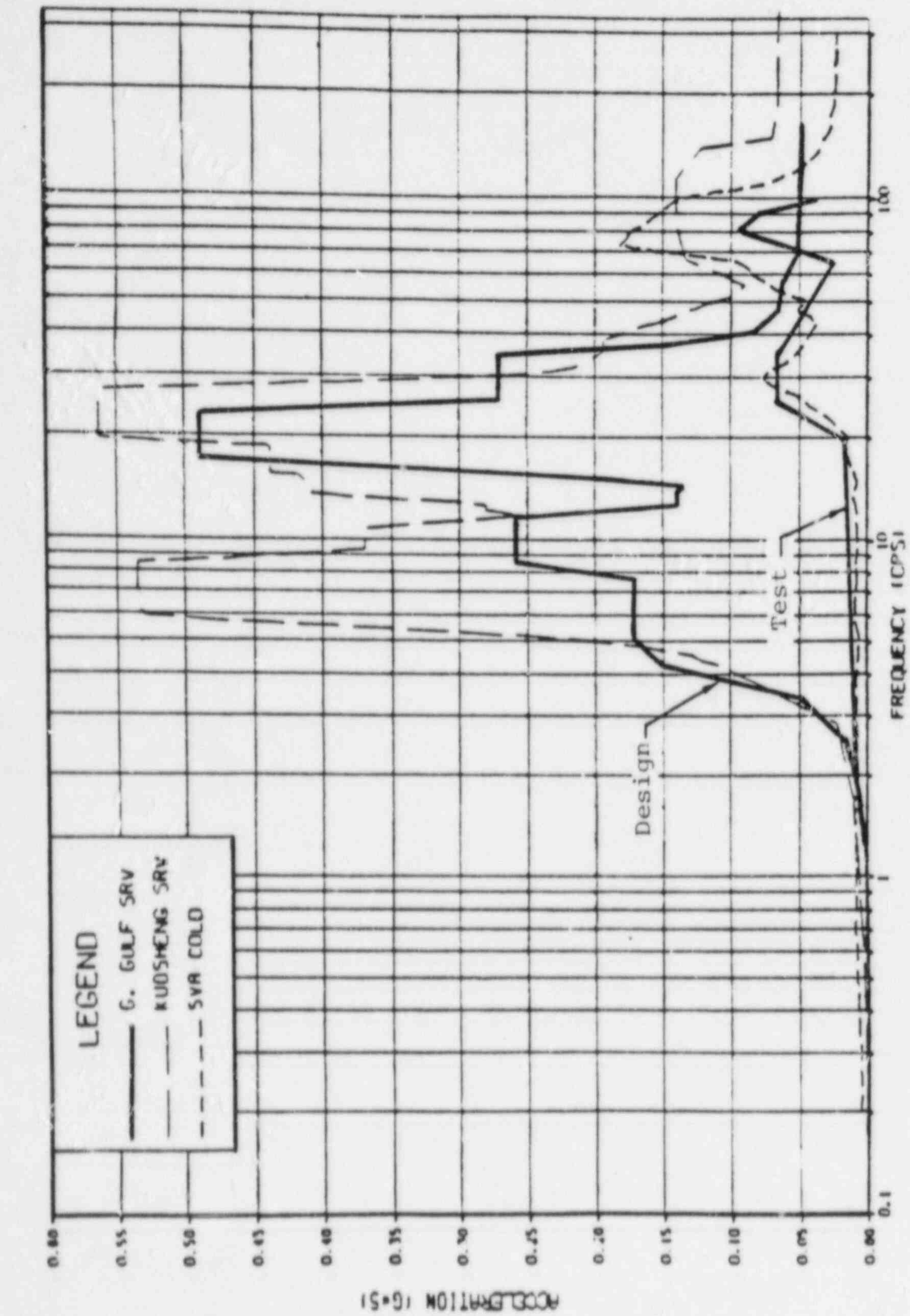


Figure 9.22

RESPONSE SPECTRA COMPARISON - GRAND GULF TO KUOSHENG
ACCELEROMETER A24, DRYWELL EL. 182.17, VERTICAL

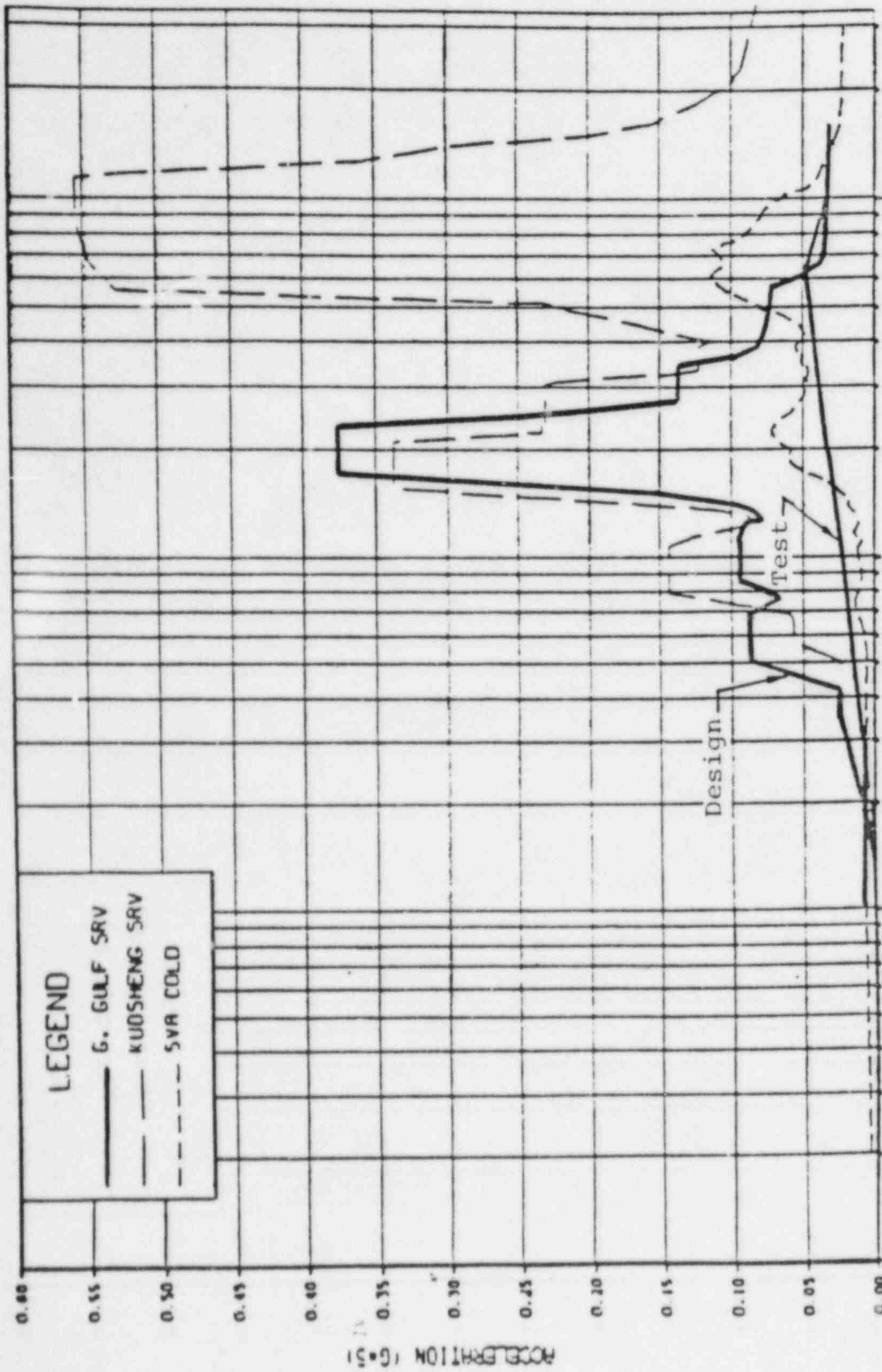


Figure 9.23

RESPONSE SPECTRA COMPARISON - GRAND GULF TO KUOSHENG
ACCELEROMETER A25, PEDESTAL EL. 121.42, HORIZONTAL

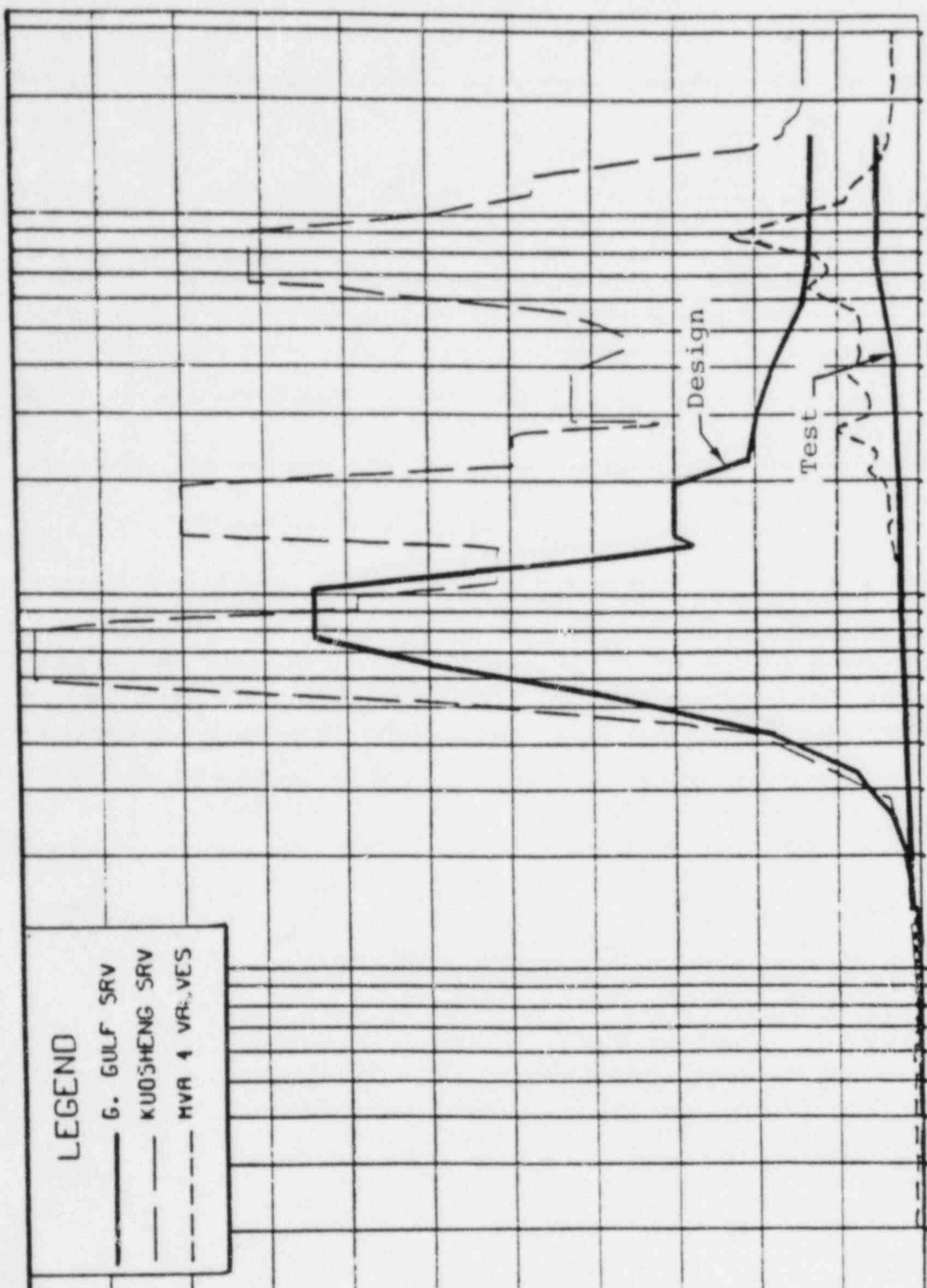


Figure 9.24

RESPONSE SPECTRA COMPARISON - GRAND GULF TO KUOSHENG
ACCELEROMETER A26, PEDESTAL EL. 121.42, VERTICAL

10.0 CONCLUSIONS

Review of the data collected during the SRV tests clearly demonstrates that the objectives of the test program have been met. The major conclusions drawn from the test data are:

- The measured peak pressures for SVA, CVA and MVA are generally less than the predicted values and are well below the Grand Gulf design values.

- The pressure time history wave form compares favorably to the General Electric Company's GESSAR predicted wave form used for the Grand Gulf plant design. The initial high frequency portion of the wave form is not as pronounced as that measured at Kuosheng and has little effect on Grand Gulf structures, piping and or equipment.

- The measured strains for the containment basemat and wall liners, the quencher support and submerged piping are less than half the predicted values.

- The peak measured zero period accelerations (zpa) are well below the predicted values at all locations. The peak measured piping and equipment accelerations are small compared to predicted values.

- The envelope spectra developed for the SVA, CVA and MVA cases are small compared to the design spectra for frequencies below 60 Hz. In three cases the test spectra exceed the design spectra at frequencies above 40 Hz. However, this does not result in significant strain response as shown by

the small strain levels and low accelerations of the containment attached piping.

It is concluded that the GESSAR methodology used for the Grand Gulf plant design, reported in Appendix 6D of the Grand Gulf FSAR, provides a design which is conservative and has considerable margin for SRV discharge loads.

11.0 REFERENCES

1. Letter, L.F. Dale (MP&L) to H.R. Denton (NRC) AECM-82/150, Dated April 13, 1982.

2. Letter, L.F. Dale (MP&L) to H.R. Denton (NRC) AECM-85/0076, Dated March 11, 1985.

3. "Grand Gulf In-Plant Safety Relief Valve Test - Test Plan", NUTECH Document No. MPL-01-008, Revision 3.

4. "Grand Gulf In-Plant Safety Relief Valve Test - Shakedown Tests - Grand Gulf Startup Test Procedure 1-M62-SU-78-3 (Supplement 1)", NUTECH Document No. MPL-01-010, Revision 5.

5. "Grand Gulf In-Plant Safety Relief Valve Test - Matrix Tests - Grand Gulf Startup Test Procedure 1-M62-SU-78-3 (Supplement 2)", NUTECH Document No. MPL-01-012, Revision 5.

6. "Grand Gulf In-Plant Safety Relief Valve Test - Acceptance Criteria for Real Time Pressure Measurements", NUTECH Document No. MPL-01-035, Revision 2.

7. "Grand Gulf In-Plant Safety Relief Valve Test - Location and Acceptance Criteria for Accelerometers", NUTECH Document No. MPL-01-042, Revision 1.

8. Letter, R.S. Trickovic (Bechtel) to M. Taylor (NUTECH), VB-81/0608, Nov. 25, 1981 and NUTECH Calculation File No. 32.801.0341, Revision 1.

9. Containment Loads Report (CLR) - Mark III Containment, GE Document No. 22A4365, Revision 4.

10. NUTECH Report ZTP-06.310, "Final Test Report, Safety Relief Valve Discharge Test, Kuosheng Nuclear Power Station Unit No. 1", Revision 0, Dated August 16, 1982.

11. Letter, L. F. Dale (MP&L) to H. R. Denton (NRC) AECM-85/0179, Dated June 6, 1985.

12. Letter, L. F. Dale (MP&L) to H. R. Denton (NRC) AECM-85/0196, Dated June 18, 1985.

13. Letter, L. F. Dale (MP&L) to H. R. Denton (NRC) AECM-85/0212, Dated July 3, 1985.

14. Letter, T. M. Novak (NRC) to J. B. Richard (MP&L) Docket No. 50-416 "Grand Gulf Nuclear Station Unit 1 - Safety Relief Valve In-plant Tests," Dated July 23, 1985.

15. "D. C. Shift on Vibration Measurements in Nuclear Power Plants," Domenico De Lucchi, The Journal of Environmental Sciences, May-June, 1982.

16. Letter, L. F. Dale (MP&L) to H. R. Denton (NRC) AECM-82/79, Dated March 15, 1982.

APPENDIX A

SIGNAL CONDITIONING EQUIPMENT AND DATA ACQUISITION SYSTEM

Signal Conditioning and Data Acquisition System

Strain gauges and pressure sensors were conditioned with a Vishay 2100 signal conditioning/amplifier system. The Endevco accelerometers inside the containment had signal conditioning provided by an Endevco Model 2652M11 remote charge converter and an Endevco Model 4479.1M3 Mode Card. The Endevco accelerometers outside the containment had signal conditioning provided by an Endevco Model 2721AM1 charge amplifier.

Vishay Signal Conditioner

The Vishay 2100 was be used to condition the strain gauge and pressure transducers. This conditioner and amplifier system is a DC voltage system with one power supply and ten amplifiers for each 5-1/2 inch high rack mount chassis. This system features independently variable excitation for each channel (1-12 VDC), and will accept quarter-, half-, and full-bridge inputs as well as DC signals from other than bridge sources. Internal to each amplifier channel are 120-ohm and 350-ohm bridge completion components for quarter- and half-bridge gauges, as well as internal shunt calibration resistors to simulate approximately 11000 microstrains. Each channel has a bridge balance network that will offset a 13000 microstrain imbalance, and an always-active LED null indicator and balance resistors to compensate for line resistance.

The 2100 System has a signal output from 0 to 10 VDC up to 100 mA with a frequency response of 5 KHz. All signal and power outputs are current-limited for short circuit protection. Transducer excitation and input signals were connected to the 2100 system using a 10-pin Cannon connector with output signals routed to a 3-pin Cinch Jones connector at the rear of the system.

After transducer hookup, normal setup procedure for the Vishay 2100 system only requires offset balancing and output gain adjustment. This system will accommodate any common data collection or monitoring equipment.

- Specifications

- Bridge Completion:	1/4-bridge completion network per channel
- Bridge Balance Range:	3000 microinches/inch
- Calibration:	Internal calibration of 1%
- Amp Gain:	100 to 2000 continuous or steps of 100, 500, 1000 and 2000
- Input:	Differential
- Input Impedance:	25 MΩ differential or common mode
- Output:	10V maximum
- Linearity:	0.05% at DC
- Stability:	0.5% after 15 minutes

Remote Charge Converter Signal Conditioner

The Model 2652M11 is a charge-to-voltage converter designed for use with piezo-electric transducers. The Model 4479.1M3 plug-in mode card is a signal conditioner designed to provide power to, and condition the signal from, the Model 2652M11 converter.

- Description

  The charge converter, located near the transducer, converts the electrical charge generated by the transducer to a low impedance voltage signal. The output is essentially unaffected by the length of the cable or changes in cable capacitance between transducer and driver. Only a single coaxial cable or a shielded, twisted pair is required between the 2652M11 converter and the 4479.1H3 mode card.

Circuitry on the plug-in card provides a constant current for the converter, a voltage amplifier, and a range switch. A calibrated dial is also provided to set in transducer sensitivity. Full-scale output of 2.5 volts peak is obtained for input measurements of 0.1, 0.3, 1.0, 3, 10 and 30 g's.

Performance Specification: Remote Charge Converter

- Electrical Characteristics
  - Input Characteristics

    Input Connection: The input is single-ended with one side connected to signal ground.

    Input Source Impedance: 25 MΩ minimum

    Source Resistance: The input is restricted to capacitive-type devices and should not be loaded with less than MΩ.

    Source Capacitance: The maximum allowable source capacitance to meet all specifications is 20,000 pF.

  - Output Characteristics

    Output Connection: The output is single-ended with one side connected to signal ground.

    Minimum Load Impedance: The minimum load impedance to meet all specifications depends on the capacitative load and bandwidth and should be such that the load current does not exceed 8 mA pk.

    Minimum Linear Output Voltage: 13.0 V pk-pk.

    Output Bias: 18 V typical.

    Output Impedance: Less than 5Ω.

Residual Noise: Less than the total of 0.6 pC rms plus 0.005 pC rms per 1000 pF of source capacity referred to the input.

- Transfer Characteristics

  - Sensitivity: 0.2 mV/pC.

  - Accuracy: ± 1% of full-scale with source capacities of 1000 pF or less.

  - Gain Change vs. Source Capacitance: The gain will change less than 0.05% per 1000 pF change in source capacitance.

  - Frequency Response: ± 5% 1 Hz to 10 KHz (with reference to 1 KHz response).

  - Linearity: 0.5% of reading from best-fit straight line approximation to the curve of output amplitude vs. input amplitude.

  - Harmonic Distortion: 0.2% maximum.

  - Gain Stability with Time and Temperature: Less than 2% over the temperature range as specified below.

- Operating Temperature Range: -55°C to +85°C.

- Power Requirements
  The Model 2652M11 charge converter is powered from a constant current source with the following characteristics:

- Current: 6 mA quiescent plus current required to drive load impedance. Combination not to exceed 14 mA.

- Compliance: 25 V minimum; 26 V maximum.

- Output Impedance: 40 kΩ minimum.

- Noise: 1 microamp pk-pk maximum.

- Connection: The current source is connected between the output and the common terminals on the Model 2652M11 converter with the output terminal sinking current.

- Case to Signal Ground Isolation: > 10MΩ @ 100 vdc.

Performance Specification: Mode Card Model 4479.1M3

- Input Characteristics

  - Input Connection: Single-Ended.

  - Input Resistance: 1000Ω in-series with 390μF.

- Output Characteristics

  - Output Connection: Single-Ended.

  - Linear Output Voltage: ± 2.5 V pk, Full-Scale.

  - Linear Output Current: ± 2.5 mA pk, maximum.

- Output Impedance: 50Ω, maximum, in-series with 200 μF.

- Power

  +30 V dc

- Ground

  Signal ground is isolated from every other channel and rack enclosure.

- Transfer Characteristics

  - Full-Scale Ranges for Sensitivities: 1 to 10 pC/g: 1, 3, 10, 30, 100, 300g 10 to 100 pC/g: 0.1, 0.3, 1, 3, 10, 30g

  - Actual Gain: 0.8 to 2500 mV/pC.

  - System Accuracy: ± 3% of F.S., any range, at +24°C (+75°F) and source capacitance of 1000 pF, maximum.

  - Gain Stability: Better than 0.5% per 1000 pF source capacitance. Better than 2%, -10°C to +65°C (+15°F to +150°F). Gain decreases approximately 1% for every 10Ω of cable resistance.

  - Frequency Response: ± 5%, 1 Hz to 10,000 Hz.

  - Linearity: ± 0.5% of reading from best straight line.

- Total Harmonic Distortion: 0.2%, maximum.

- Residual Noise: Less than the total of 0.0075 pC rms plus 0.0025 pC rms per 1000 pF source capacitance referred to input plus 0.5 mV rms referred to output.

Performance Specification: Charge Amplifier Model 2721AM1

- Input Characteristics

  - Input Connection: Single-ended with one side connected to circuit common; restricted for use with capacitive devices

  - Source Impedance: 1 kΩ minimum shunt resistance; 30,000 pF maximum shunt capacitance

  - Maximum Input: 30,000 pC pk without overload

  - Slew Rate: 1,000 pC/μs maximum

- Output Characteristics

  - Output Connection: Single-ended with one side connected to circuit common

  - Linear Output Voltage: ±10 V, maximum
  - Linear Output Current: ±2 mA, maximum

  - Output Impedance: 10Ω ±10%

- Residual Noise: Nc < 0.03 pC rms +0.008 pC rms per 1,000 pF of source capacitance, referred to input

  $Nr = \frac{100}{Rs}$ pC rms (typical)

  where Rs < 100 Ω

  $\text{Noise} = N_C{}^2 + N_r{}^2$

- Transfer Characteristics

  - System Sensitivity: Amplifier gain is continuously adjustable to allow for indicated calibrated system sensitivity for transducers with sensitivities of 1 to 110 pC/g

  - Indicated ranges: 1, 3, 10, 30, 100 mV/g for 1 to 11 pC/g; 10, 30, 100, 300, 1,000 mV/g for 10 to 110 pC/g

  - Gain Accuracy: ±1% of actual gain for source impedance > 10 kΩ and/or < 10,000 pF; ±2% of gain for source impedance 1 kΩ to 10 kΩ and/or 10,000 pF to 30,000 pF

  - Gain Stability: ±200 ppm/°F, maximum

  - Frequency Response: > ±5%, 1Hz, with source impedance > 300 kΩ; ±5%, 3Hz to 10,000 Hz with source impedance 100 kΩ 300 kΩ; ±5%, 5 Hz to 10 kHz with source impedance 10 k0 to 100 kΩ; ±5%, 50 Hz to 10 kHz with source impedance 1 kΩ to 10 kΩ

- Operating temperature range 0°C to + 75°C

Digital Data Acquisition and Recording

The digital data acquisition, recording and playback system (DARPS) is the Quad Systems, Inc. (QSI) Model 721. This system provides fast, accurate and flexible data gathering from an exceptionally wide variety of signal sources (both digital and analog).

The following summarizes the basic capabilities of the digital data acquisition system.

- Q.S.I. System Performance Characteristics

  - Record Electronics

    Analog Input Channels: Existing system 224 channels, expandable to 256 channels in 16 channel blocks

    Digital Input Channels: Expandable to 32 channels, up to 16 bit parallel with handshake transfer

    Frequency Response Range: 200 Hz

    Throughput Rate: 1000 samples/sec/channel

    Recording Capacity: Up to 145 Megabytes per reel

    Analog Input Impedance: 10 MΩ

    Conversion Method: Successive approximation with S/H input amplifier

Conversion Code: 2's complement binary

Conversion Resolution: 12 bits including sign

Linearity: 1/2 LSB

Input Level-Analog: 5V FS, 15V FS maximum over-voltage protected

Digital: Standard TTL Levels

Time Code Data: Days, hours, minutes and seconds may be entered into tape records as required

Header Data: Manually entered by operator via front panel keyboard

Power: 1800 W, 110 VAC, 110%, 50-60 Hz

- Playback Electronics

Number of Output Channels: Existing system-four channels expandable up to 10 channels

Throughput Rate: Up to 250,000 samples per second

Speed-Up Factor: Up to 1000:1 and beyond limited only by throughput rate

Conversion Code: 2's complement binary

Conversion Resolution: 12 bits including sign

Setting Time: 3 microsec to 1/2 LSB

Slew Rate Output Voltage: 20V/second standard for 5V FS; other ranges optional

Output Current: 5 mA

Output Filter: 4-pole active Bessel, Butterworth or Tschebychev optional

Conversion Accuracy: 0.05% FS LSB at 25°C

Temperature Coefficient: 20 ppm/°C

Time Code Data: Days, hours, minutes and seconds may be read from tape records and displayed

- Tape Transport Characteristics

Format: IBM-compatible

Number of Tracks: 9-track

Density: 6250 BPI, GCR

Record Length: 4096 bytes

Tape Speed: 125 ips

All signal inputs to the system are processed, formatted, and written in an IBM-compatible format on digital magnetic tape. The tapes generated may then be processed on any computer system

(supporting industry standard magnetic tapes) for data reduction, analysis, and reformatting to any desired standard.

Internally, the system consists of four main subsystems: 1) an analog multiplexer, 2) precision analog-to-digital converter, 3) high-speed digital magnetic tape recorder, and 4) electronic control logic. Several factors contribute to the unusually high accuracy and throughput of this system. The analog-to-digital converter is a precision, 12 bit (11 bits plus sign) unit, with crystal referenced sampling rate. The resulting low sample interval jitter eliminates the wow and flutter problems of analog recorders. The digital magnetic tape unit is a high-speed (125 ips), very high density (6250 BPI Group Code Recording (GCR)) device. This enables an extremely high data throughput for the system. The GCR technique provides for a very low error rate by correcting many recording errors on-the-fly. Finally, semiconductor memory is used to buffer data flow through the system. This allows data acquisition and recording functions to proceed independently, for the highest possible system throughput (up to 250,000 samples/sec).

This system provides for on-the-spot playback of recorded data, with reconversion to analog form. It is also possible to speed up or slow down the playback over a 1000:1 range, with no loss of accuracy. Time data retrieved from the tape are locked to the signal data and thus track any speed-up or slow-down.

Analog Monitoring System

The analog monitoring system consisted of conventional analog instruments oscillographs, and a spectrum analyzers. The monitoring system has four functions: 1) real-time monitoring of signals, 2) display medium for after-the-run quick-look replay of digitally-recorded signals, 3) redundant recording of any specially selected critical signals, and 4) system operational check/calibration.

Oscillograph Recorder

Selected channels of test data were be presented in real-time through the use of light beam oscillograph recorders. Honeywell Model 1508 recorders, with M-1000, M-1600 or M-400-350 galvanometers, are ideally suited for this application. This equipment provided for the recording of data over a frequency range from DC to greater than 200 Hz, and permitted validation of incoming data before proceeding to the next test phase.

Valve ON reference timing marks were recorded on each oscillograph record. However, due to a problem in the valve on electronics this signal had a built-in time delay and, therefore, could not be used as a true indication of test start.

Spectrum Analyzers

A Spectral Dynamics SD375 FFT analyzer was used, with a SD422 Video printer, to provide more detailed on-site data analysis, as required.

APPENDIX B

INSTRUMENTATION DESCRIPTION

SENSOR REQUIREMENTS

Type of Sensor: Pressure Transducer

Sensor Identification(s): P1 to P20, P26 to P32

Location: Suppression Pool

Expected Response: 10 - 35 psia

Frequency Range: 0 Hz to 200 Hz

Environmental Conditions:

Atmosphere: Water, Air, Steam

Temperature: 50°F to 200°F

Pressure (psia): 50

Manufacturer/Model: Bell & Howell/CEC-1000-0207

Operating Range/Accuracy: 0 to 100 psia/±0.20% of Full Range Output (F.R.O.)

Additional Information:

Sensors were supplied with special 1/2" thread and six electrical brazed terminal cups to replace standard electrical connector. Sensors have 75' of steel sheath cabling. Extension cabling is P/N 6XE 24-1936STJ, Type "E" Teflon wire, overall stranded shield with Teflon tape jacket. All wires meet fire protection guidelines of NFPA-803 and IEEE 383-1974. Signal conditioning shall be supplied via Vishay Model 2100.

SENSOR REQUIREMENTS

Type of Sensor: Pressure Transducer

Sensor Identification(s): P21 to P24

Location: SRV Discharge Line and Quencher

Expected Response: 0 to 700 psia

Frequency Range: 0 Hz to 200 Hz

Environmental Conditions:

Atmosphere: Water, Air, Steam

Temperature: 400°F

Pressure (psia): 700

Manufacturer/Model: Bell & Howell/CEC-1000-208

Operating Range/Accuracy: 0 to 1000 psia/±0.22% of F.R.O.

Additional Information:

Outer case of sensors P23 and P24 is exposed to water, air, and steam at 50 psia and 50° to 200°F. Outer cases of sensors are exposed to air at 100% relative humidity (R.H.), 42.2 psia (structural integrity test (S.I.T.) pressure) and 135°F. Sensors P23 and P24 have 75' of steel sheath cabling. Sensors P21 and 22 P24 have 10' of steel sheath cabling. Extension cabling is P/N 6XE 24-1936STJ, Type "E" Teflon wire, overall stranded shield with Teflon tape jacket. All wires meet fire protection guidelines of NFPA-803 and IEEE 383-1974. Signal conditioning shall be supplied via Vishay Model 2100.

SENSOR REQUIREMENTS

Type of Sensor: Pressure Transducer (Low Range)

Sensor Identification(s): P25

Location: SRV Discharge Line

Expected Response: 0 to 25 psia

Frequency Range: 0 Hz to 200 Hz

Environmental Conditions:

Atmosphere: Air, Water, Steam

Temperature: 400°F

Pressure (psia): 700

Manufacturer/Model: Teledyne Taber/2215

Operating Range/Accuracy: 0 to 50 psia/with 1000 psi over-range

Additional Information:

Outer case of sensor will be exposed to air, 100% R. H. at 42.2 psia (S.I.T. pressure) and 135°F. Signal conditioning shall be supplied via Vishay 2100. Wiring shall be 6XTF Tefzel wire, overall stranded shield with Tefzel tape jacket. All wire shall meet fire protection guidelines of NFPA-803 and IEEE 383-1974.

SENSOR REQUIREMENTS

Type of Sensor: Strain Gauge

Sensor Identification(s): S1 to S34

Location: Quencher Support, Pool Line and Submerged Structures

Expected Response: See Table 4.2

Frequency Range: 0 Hz to 200 Hz

Environmental Conditions:

Atmosphere: Water, Air, Steam

Temperature: 50°F to 200°F

Pressure (psia): 50

Manufacturer/Model: S1-S4: Ailtech/MG125/31-01HV-75-SA106
S5-S34: Ailtech/MG125/31-01HV-75-6S

Operating Range/Accuracy: 0.20 in/in/± 3%

Additional Information:

Temperature compensation for -SA106 is based on SA106 GR.B Steel; temperature compensation for -6S is based on 1018 steel. Sensors have 75' of 1/16" O.D. steel sheath cable with three open leads. Sensors were hydrostatically tested to 2500 psig and 500°F prior to shipment by the vendor.

Extension wire is P/N 3XE 24-1936STJ, Type "E", 600V. Teflon wire with stranded shield and Teflon jacket. All wires meet fire protection guidelines of NFPA-803 and IEEE 383-1974. Signal conditioning shall be supplied via Vishay Model 2100.

SENSOR REQUIREMENTS

Type of Sensor: Accelerometer

Sensor Identification(s): A1 to A6, A13, A14, A53 to A56

Location: Outside Containment

Expected Maximum Response: 0.10g

Frequency Range: 1 Hz to 200 Hz

Environmental Conditions:

Atmosphere: Air

Temperature: 135°F

Pressure (psia): 14.7

Manufacturer/Model: Endevco/7703-100 or 7704-100

Operating Range*/Accuracy: 0 to 500g's/±5% full scale

Additional Information:

Wiring will be coaxial softline cable (29AWG).

Wire shall meet fire protection guidelines NFPA803 and IEEE 383-1974. Additional equipment to be used in conjunction with the above accelerometers will be an Endevco charge amplifier, Model 2721AM1.

* The appropriate accelerometer full scale range for the test will be set by adjusting the gain on the charge amplifier to the proper value determined during shakedown tests.

SENSOR REQUIREMENTS

Type of Sensor: Accelerometer

Sensor Identification(s): A7 to A12, A15 to A52

Location: Containment/Drywell

Expected Maximum Response: A7 to A29 = 0.20g
A30 to A52 = 5.5g

Frequency Range: 1 Hz to 200 Hz

Environmental Conditions:

Atmosphere: Air

Temperature: 135°F, 100% relative humidity; except A38 to A52 where the maximum temperature is 450°F.

Pressure (psia): 15.4

Manufacturer/Model: Endevco/7708-200 or 7705-200 Operating Range*/Accuracy: 0 to 150 g's/±5% of full scale

Additional Information:

Wiring is Teflon wire, overall stranded shield with Teflon jacket (24 AWG 2 conductors, 19/36 stranded jacket).

Wire shall meet fire protection guidelines NFPA803 and IEEE 383-1974. Additional equipment to be used in conjunction with the above accelerometers will be an Endevco remote charge converter Model 2652M11 and an Endevco signal conditioner Model 4479.1.

* The appropriate accelerometer full scale range for the test will be set by adjusting the gain on the Endevco signal conditioner to the proper value determined during shakedown tests.